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AUTOMOTIVE MANUFACTURER RISK ANALYSIS: MEETING THE AUTOMOTIVE FUEL ECONOMY STANDARDS

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FINAL REPORT

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16. Abstract

A risk analysis model of the automobile industry is developed in order to assess the impact of the Automotive Fuel Economy Standards (AFES) on each of the manufacturers in the industry. Data from reports written or sponsored by DOT, and from publicly available sources are used to illustrate the application of the model. The results yield some insight into how the corporate environment, the manufacturers' strategy, and the AFES interact with one another.

Several conclusions based on the analysis are presented. First, and most importantly, it is shown that the AFES tend to increase concentration in the industry, and to favor, in a relative sense, the larger manufacturers having a full product line. Second, since increased numbers of small cars need to be sold to meet the AFES, larger cars become more expensive while smaller cars become less expensive. Finally, several different economic and manufacturing scenarios are analyzed in detail leading to a variety of more specialized insights.

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PREFACE

Most of the data used in this report are based on reports written by or sponsored by the U.S. Department of Transportation (DOT). The remaining data are based on publicly available reports in most cases. The personnel of the DOT/Transportation Systems Center, Cambridge, Massachusetts, provided valuable assistance in carrying out this study. Finally, throughout the study Professor William J. Abernathy of the Harvard Business School was very helpful in setting the direction of the study and critiquing the various findings.

METRIC CONVERSION FACTORS

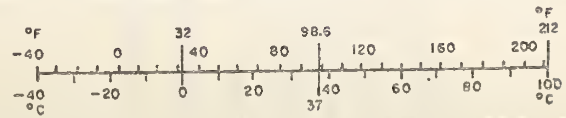
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

On December 27, 1975, the Energy Policy and Conservation Act (Public Law 94-163) was passed by Congress requiring all automobile manufacturers to achieve a schedule of improved fuel economy for new car sales in the United States. The Act requires that the fleet-weighted average fuel economy, in miles per gallon, for each manufacturer, meet or exceed a specified minimum standard that increases over time. The new minimum standards require that the fleet-weighted average fuel economy nearly double over roughly a ten year period. Table 1-1 gives the standards initially established in the Act.

TABLE 1-1 FLEET-WEIGHTED FUEL ECONOMY

OF NEW CAR SALES

Actual	1974	14 mpg.
Required	1978	18 mpg
	1979	19 mpg
	1980	20 mpg
	1981-84	build up to the 1985 standard to be determined by the Secretary of Transportation
	1985	27.5 mpg

This study is concerned with the extraordinary commercial risks placed on the automobile manufacturers by the addition of these regulatory requirements. The problem of evaluating the risks inherent in these regulations is approached through the use of a methodology commonly known as risk analysis.

Risk analysis is a systematic approach which can be used to analyze complex decision situations involving uncertainty. Risk analysis, in its most simple form, involves a computer simulation of the business environment for the purpose of evaluating a specific strategy explicitly taking into account the most important uncertainties. The

uncertainties are combined using Monte Carlo simulation techniques to obtain risk profiles, or probability distributions, of key summary measures of performance. Thus, one of the contributions made by this study is methodological in nature, as the study should be helpful in understanding how to apply risk analysis to other similar situations.

The main purpose of this study is to develop a risk analysis model of the automobile industry in order to assess the impact of the Automotive Fuel Economy Standards (AFES) on each of the manufacturers in the industry. Data that approximates the characteristics of each of the U.S. automobile manufacturers are used to illustrate the application of the model. The chief contribution of this study is to take different bits and pieces of data, mostly from several different reports written or sponsored by DOT,[1] and to use these data to arrive at an analysis of the impact of the AFES on the automobile industry. This approach serves to highlight the fact that in order to analyze the impact of the AFES, one must understand the various interrelationships among the different components of the situation under study and the various pieces of data available. This study formulates several of these interrelationships in mathematical terms and integrates them into a risk analysis model to analyze the impact of the AFES. The results yield some insights into how different aspects of the situations interact with one another.

In order to structure the risk analysis for the automobile industry, uncertainty has been categorized into two classes: contextual (or exogenous), and endogenous. The contextual uncertainty arises from two sources: (1) economic conditions (overall business), and (2) marketing environment (automotive sales). The sources of endogenous uncertainty include technology, warranty*, and manufacturing conditions. While there are several areas of uncertainty, the overall impact of all of these results in financial performance. The objective of this analysis, therefore, is to assess the effect of the AFES on the financial performance of each of the manufacturers, while taking into account the uncertainties mentioned above.

In this study a <u>conditional</u> risk analysis is carried out. That is, each situation is analyzed <u>conditional</u> on the contextual uncertainty being resolved. Fixed values are assumed for the variables which are the source of the contextual uncertainty; that is,

* Warranty risk has been excluded from the analysis since it was not possible to find any data on warranty costs. However, given such data, it is fairly simple to introduce warranty risk into the analysis.

1. INTRODUCTION

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economic and market variables. Setting the values of these variables is called "defining a scenario." Conditional on each scenario, several different cases can then be examined under certainty using sensitivity analysis. This involves changing the assumptions concerning the values of the variables which are the source of the endogenous uncertainty and analyzing the impact. In addition, it can also be assumed that only the probability distributions of the variables, which are the source of the endogenous uncertainty, are known; this case is called the "probability case." The model then produces risk profiles, or probability distributions, for various summary measures of performance for each manufacturer. The reason for carrying out the analyses conditional on a scenario is so that the contextual uncertainty does not swamp out the risks imposed on the manufacturers that directly result from attempting to meet the AFES.

The first step in the approach is to formulate a set of relationships, or a model, to determine the financial performance of the manufacturers, given certain assumptions about their strategy for meeting the AFES, their current and future environments, and other factors beyond their control. In other words, the risk analysis model is designed to estimate the manufacturers' performance, given assumptions about their specific strategy, and about the resolution of the contextual and endogenous uncertainties.

Designing such a model requires a large amount of data. It should be emphasized that the objective of this study is not to generate data, but rather to develop a model and to perform a risk analysis using the data already available. Thus, almost all the data used in this study is from reports written or sponsored by DOT. Some data is based on publicly available documents [2,3,4,] and [5,] and on consultations with industry experts.

In order to give some of the spirit of the risk analysis model that is developed in Sections 2 and 3, some of the underlying assumptions of the approach are pointed out here.

1.1 Market Demand and Consumer Preferences

In the analysis, the aggregate demand projections, by model size, from 1976 to 1985, are

forecast by the Wharton Econometric model of the U.S. automobile Industry. These projections account for demographic variations in the U.S. population over this period, which result in a slight upward movement in the desired size of cars. The Wharton projection does not anticipate any increase in "fuel economy consciousness" on the part of the consumer, which would be manifested as a greater preference for smaller cars than projected by the WEFA model.[6]

1.2 Inflation

The analysis is carried out in 1976 dollars. This is equivalent to assuming that price adjustments for wages, capital goods, materials, services, and final product prices are uniform. That is, inflationary increases in any factor are passed through uniformly.

1.3 Manufacturing Costs

Manufacturing costs are assumed to conform with the industry's historical experience, except for increases due to the adoption of new technological options to improve fuel economy. Increased manufacturing costs resulting from other regulatory requirements such as pollution control and safety are not included except in that they reduce fuel efficiency.

1.4 New Technologies to Improve Fuel Economy

Each manufacturer is scheduled to introduce technologies to improve fuel economy according to a time table suggested in U.S. Department of Transportation data.[7] These are all available technologies including downsizing, material substitution, improved power train components, lubricants, accessories, aerodynamic body configurations, new tires, and so forth.

1.5 Fuel Economy

The corporate fleet-weighted average fuel economy achieved by each manufacturer is determined by the size of cars produced, and the technological options implemented. The mix of cars produced for sale each year is adjusted by the risk analysis model to strictly meet the legally required fuel economy level for that year. The model assumes that each manufacturer will satisfy the AFES in every year. The mix of car sizes produced by each manufacturer starts in 1977 with his historical product mix. The model determines the amount of mix shift, if any, that is needed to meet the legally required fleet-weighted average fuel economy for each year.

1.6 Vehicle Price

The sale prices of various size-class cars are computed by the model, with the assumption that the price differential between the various size-class cars is such that the market is cleared. It is assumed that the average car price is constant over time, with some qualifications which are discussed later. Both these assumptions, which are congruent with the WEFA model, are discussed in greater detail in Section 2.

However, it should be pointed out here, that it is possible to make alternative assumptions about the pricing process. For example, one could assume that General Motors sets the prices for the various size-classes on a cost plus mark-up basis, and the other manufacturers set the same prices as General Motors. That is, General Motors is assumed to be the price leader of the industry. This assumption would not be consistent with the WEFA model. Since the demand projections from the WEFA model are used, it is appropriate, in order to be internally consistent, that the assumptions about the pricing process be congruent with the WEFA model.

1.7 Profit and Financial Ratios

Given production volume, sales mix, manufacturing overhead and fixed cost, and sales prices, the model computes after-tax profit for each manufacturer. Cash flow is determined by capacity expansion (if any), investment in new technological features, depreciation, debt charges, and so forth. Long-term debt is allowed without limit to

balance the cash requirements. For this reason, the long-term debt position provides a useful overall indicator of a given manufacturer's risk position.

The four major U.S. automobile manufacturers are obviously very complex organizations. It is clearly impossible to capture the full complexity of their operations in a model of any reasonable size. However, the main difficulty in designing a model such as the one developed for this study is that all the relevant data is not available. Much of the relevant data is confidential and not released by the companies.

In this study four major U.S. automobile manufacturers labelled G F C and A are considered. Manufacturers G F C and A are as close approximations to the North American passenger car businesses of General Motors, Ford, Chrysler, and American Motors respectively, as possible, given the data available to us and the objectives of the study.

Because of the approximations made in the data input to the model, the results generated by the model should be interpreted with some caution. The model developed in this study should be used to analyze the <u>relative</u> impact on the manufacturers due to the AFES, given certain assumptions about the environment faced by the manufacturers. "Relative impact" refers to either the impact on a manufacturer relative to that of the other manufacturers or its own initial position.

The foreign manufacturers who market cars in the U.S. have been aggregated and are considered as just one manufacturer. No attempt is made to assess the impact of the AFES on the foreign manufacturers. For all the manufacturers considered in this analysis, the concern is only with their U.S. passenger car operations, and not the whole corporation. For the sake of semantic simplification, the term "manufacturer" is used to mean the U.S. passenger car operations of the automobile company.

An overview of the AFES model and most of the basic data are described in Section 2 while a more detailed description of the model including the appropriate equations is given in Section 3. The AFES model has been written in FORTRAN and is implemented on the Harvard Business School PDP-10 computer. The computer output from one particular scenario is given in Appendix A. Some instructions for using the computer

program are given in Appendix B. The data files in the format required by the computer program are given in Appendix C. Finally, the computer program itself is given in Appendix D.

In Section 4, several cases under the Nominal scenario are analyzed, that is, the scenario uses the one-point currently available estimates for the values of the contextual variables. In Section 5, several alternative scenarios are analyzed in an attempt to understand the effects of different AFES, market, and economic conditions.

2. OVERVIEW OF THE AFES MODEL

2.1 General

The objective of the AFES model is to estimate the financial performance of each of the manufacturers, given assumptions about their strategy for meeting the Automotive Fuel Economy Standards (AFES), and about the resolution of various contextual and endogenous uncertainties. In order to accomplish this objective, specific relationships among a large number of variables and parameters have to be identified and formulated. These relationships can be conveniently categorized into seven modules. The modular design of the AFES model makes it easy to change, if required, the relationships embodied in the model.

In this section the assumed manufacturers' strategy is described, and then a brief overview of each of the modules is presented in turn. The purpose of this section is to develop an intuitive understanding of the approach and data assumptions, while a more detailed description of the model is contained in Section 3.

2.2 Assumed Manufacturers' Strategy

It is assumed that the manufacturers will implement various technological options in order to meet the AFES.[8] These fuel economy measures include downsizing, material substitution, and technological improvements in transmissions, lubricants, accessories, and aerodynamic drag. The schedules for implementing these measures are manufacturer specific and are given in Tables 2-1 to 2-3. If the fleet-weighted average fuel economy (in mpg) for a manufacturer, after implementing the above fuel economy measures, is equal to or exceeds the AFES for that year, then the manufacturer is assumed to have produced the same product mix as in the previous year. However, if the fleet-weighted average fuel economy is below the AFES for that year, then the manufacturer is assumed to have changed the product mix so as to just meet the AFES. That is, the manufacturer will produce a larger proportion of small cars in order to

meet the AFES. Since the consumers may prefer a different product mix from the one actually produced by the manufacturers, it is assumed that the manufacturers will have to change car prices, either directly or indirectly, in order to sell the product mix actually produced.

TABLE 2-1. SCHEDULE FOR DOWNSIZING

	Year of Downsizing			
	Full-size	Mid-size	Compact	Subcompact
Company G	1977	1978	1979	1980
Company F	1979	1980	1978	1979
Company C	1979	1978	1981	—
Company A	—	1978	1980	1979

Source: Based on "Data Analysis for 1981-1984," Document 2, Vol. I.[9]

TABLE 2-2. SCHEDULE FOR MATERIAL SUBSTITUTION

	Year of Implementing Material Substitution			
	Full-size	Mid-size	Compact	Subcompact
Company G	1982	1986	1984	1986
Company F	1984	1985	1983	1984
Company C	1986	1983	1986	1983
Company A	—	1984	1985	1986

Source: Based on "Data Analysis for 1981-1984," Document 2, Vol. I.[9]

TABLE 2-3

SCHEDULE FOR IMPLEMENTATION OF TECHNOLOGICAL IMPROVEMENTS

	Percentage of Cars Manufactured with the Improvements				
	1981	1982	1983	1984	1985
	Company G				
Automatic transmission*	20	40	65	90	93
Manual transmission	7	7	7	7	7
Lubricants	20	40	60	80	100
Accessories	20	40	60	80	100
Aerodynamic drag	60	70	80	80	80
Rolling resistance	20	40	60	80	80
	Company F				
Automatic transmission*	25	40	50	75	85
Manual transmission	5	10	15	15	15
Lubricants	20	40	60	80	100
Accessories	20	40	60	80	100
Aerodynamic drag	60	70	80	80	80
Rolling resistance	20	40	60	80	80
	Company C				
Automatic transmission*	0	10	15	70	85
Manual transmission	0	5	15	15	15
Lubricants	20	40	60	80	100
Accessories	0	20	40	60	80
Aerodynamic drag	30	60	70	80	80
Rolling resistance	20	40	60	80	80
	Company A				
Automatic transmission*	0	0	0	25	40
Manual transmission	0	0	5	10	13
Lubricants	20	40	60	80	100
Accessories	0	0	20	40	60
Aerodynamic drag	20	40	60	70	80
Rolling resistance	20	40	60	70	80

Source: "Rulemaking Support Paper"[7]
*(TCLU)

There are a few other alternatives available to the manufacturers which are not directly considered in the above assumed strategy. (1) Reduction in acceleration performance could also be used to improve fuel consumption. This will probably take place on average with a move toward smaller engines, but no data are available to estimate that effect. (2) If the manufacturers have to change their product mix, they would use increased promotion and advertising, in addition to pricing, to sell the changed product mix. This would have the effect of increasing the revenues while simultaneously increasing the costs. Assuming that the gross margins would remain about the same, our conclusions would be unchanged. (3) The manufacturers could pursue technological options such as the diesel or stratified charge engines;[10] however, in the time frame of this analysis, the market penetration of these alternatives is assumed to be quite limited.

To the extent that a manufacturer does produce cars with diesel or stratified charge engines, his product mix will have to be changed less than the change predicted by the model. At the same time, this would have an effect on his capital costs and manufacturing costs. For Companies G and F, which would probably produce their own engines, this would have the effect of increasing their capital costs. While for Companies C and A, which might buy the diesel or stratified charge engines, this alternative could have the effect of decreasing their capital costs at the expense of increasing their manufacturing costs. Since data is not available on schedules for implementation of these options, it is not possible to include them in the model. However, given the implementation schedules and cost data, it would be straightforward to extend the model to consider diesel and stratified charge engines.

The final element of the assumed manufacturers' strategy is that there will be no increase in equity financing. (In fact, Chrysler Corporation is attempting to raise equity capital at this time; however, it is not as yet clear whether or not it will be successful.) Thus, the capital investment for implementing the fuel economy measures and other capital investments are assumed to be financed out of retained earnings and increases in long-term debt. If a manufacturer generates more cash than he uses, then the net cash inflow is used to retire long-term debt. If there is no long-term debt, then the net cash inflow is assumed to be invested in interest bearing securities. In reality,

an automobile manufacturer will undoubtedly neither reduce long-term debt very much nor invest the excess cash flow in securities. If one division of a corporation is a net generator of cash, then that cash will most certainly be used to finance investments in other programs throughout the company maintaining the debt/equity ratio for the company close to its historical level. However, since this analysis considers only the U.S. passenger car operations for each automobile manufacturer, the above treatment is a reasonable way of keeping track of the cash use/cash generation ability of a company. The reduction in long-term debt and the investment in interest-bearing securities should be thought of as investment in future technologies or other programs within the company.

2.3 Overview of the Model

The model has been designed in a modular fashion to facilitate changing the assumptions employed in any of its parts. There are seven main modules, each of which is described below. The seven modules and the flow of information between the modules are schematically represented in Figure 2-1.

It should be pointed out that the information flow depicted in Figure 2-1 is from the top down without feedback loops requiring the complex simultaneous solution of different modules. The basic assumption of the AFES model is that the industry responds to market demand as much as possible, given the constraint imposed by AFES, and that the price differentials between different size-class cars are determined by a market clearing process. The prices of various size-class cars are adjusted to sell the product mix that is produced in order to meet the AFES. This assumption is explored in greater detail later when the Price Module is discussed.

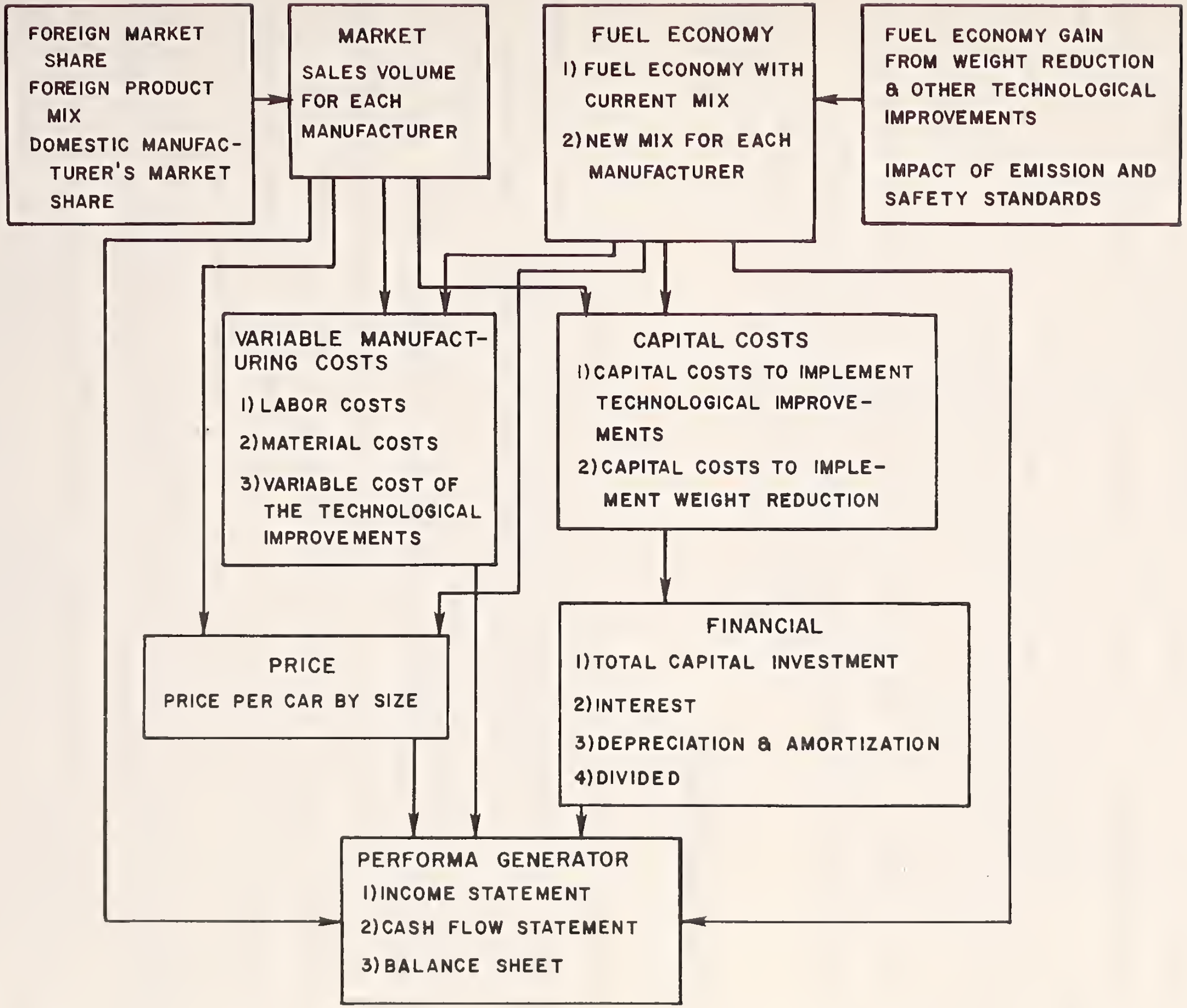

FIGURE 2-1. AN OVERVIEW OF THE MODEL

2.4 Marketing Module

The input to the Marketing Module consists of the total U.S. automobile demand and foreign market share by year (Table 2-4), foreign product mix (Table 2-5) and the domestic manufacturers' market shares (Table 2-6). It is assumed that the foreign manufacturers' product mix and the domestic manufacturers' market shares remain constant over the years. This assumption has been made because there are no estimates available as to how these factors might change over time; and also, this assumption appears to be a reasonable approximation. However, given such estimates, it would be straightforward to change the model to eliminate this assumption. Moreover, one of the scenarios analyzed in Section 5 is, in fact, one in which the foreign manufacturers change their product mix. The output from this module consists of the sales volume for the foreign manufacturers and for each domestic manufacturer by year.

2.5 Fuel Economy Module

The Fuel Economy Module takes in as input the following data for each manufacturer: previous year's product mix (Table 2-7 for year 1976), current fuel consumption by size class (Table 2-8), and schedule for implementing the various fuel economy measures. The parameters input to this module are: the impact on fuel consumption due to the various fuel economy measures (Table 2-9), the schedule of AFES, and the schedule of impacts on fuel consumption due to emission control and safety regulations (Table 2-10). The module calculates the fleet-weighted average fuel economy for each manufacturer using the previous year's product mix. If a manufacturer meets the AFES for that year, his product mix is not changed from the previous year's product mix. If the manufacturer does not meet the AFES for that year, his product mix is changed to meet the AFES. It is assumed that the manufacturer will want to minimize the change necessary in order to comply with the AFES. Furthermore, it is assumed that the proportion shifted from a given size class to the next smaller size class is the same for all size classes. The output from the Fuel Economy Module is the new product mix for each manufacturer by year.

TABLE 2-4. U.S. AUTOMOBILE DEMAND AND FOREIGN MARKET SHARE BY YEAR

Year	U.S. Automobile Demand* (million units)	Foreign Market Share**
1977	11.3	20.0%
1978	11.6	19.4
1979	11.5	18.8
1980	11.7	18.2
1981	12.7	17.6
1982	12.5	17.0
1983	12.2	16.4
1984	12.3	15.8
1985	12.4	15.2

*From the Wharton EFA Automobile Demand Model.[6]
**Based on remarks in "Data Analysis for 1981-1984, Passenger Automobile Fuel Economy Standards," Document I.[9]

TABLE 2-5. FOREIGN PRODUCT MIX

	Full-size	Mid-size	Compact	Subcompact
Nominal Scenario	0	0	.2	.8

TABLE 2-6. MARKET SHARES OF THE DOMESTIC MANUFACTURERS

Company G	Company F	Company C	Company A
56.48%	25.77%	15.39%	2.36%

TABLE 2-7. PRODUCT MIX
(in %)

(Year 1976)

	Full-Size	Mid-size	Compact	Subcompact
Foreign	0.0	0.0	20.0	80.0
Company G	27.42	41.06	18.2	13.32
Company F	23.72	23.82	22.4	30.06
Company C	13.38	24.72	36.1	25.78
Company A	0.0	14.78	66.55	18.67

Source: "Data Analysis for 1981-1984," Document 2, Vol. I.[9]

TABLE 2-8. CURRENT FUEL CONSUMPTION
(in mpg)

	Full-size	Mid-size	Compact	Subcompact
Company G	18.0	19.0	21.0	25.0
Company F	16.5	17.0	20.0	24.0
Company C	15.5	16.0	18.0	31.0
Company A	--	16.0	19.0	23.0

Source: "Data Analysis for 1981-1984," Document 2, Vol. I.[9]

TABLE 2-9. FUEL ECONOMY GAINS FROM TECHNOLOGICAL IMPROVEMENTS

Option	Gain		
	Nominal values*	Optimistic values**	Pessimistic values**
Automatic transmission	10%	11.1 %	6.88%
Manual transmission	5	5.63	4.38
Lubricants	2	2.25	1.0
Accessories	2	2.63	1.37
Aerodynamic drag	4	4.25	2.33
Rolling resistance	3	3.85	2.22

*From "Rulemaking Support Paper," NHTSA, July 1977.[7]
**Based on judgment of an industry expert.

TABLE 2-10 REGULATORY STANDARDS

Year	Automotive Fuel Economy Standard* (in mpg)	Penalty due to Emission Standards** (in %)	Penalty due to Safety Standards** (in %)
1977	17.0	0.0	0.0
1978	18.0	0.0	0.0
1979	19.0	0.0	0.0
1980	20.0	0.0	0.0
1981	22.0	0.0	1.0
1982	24.0	0.0	1.0
1983	26.0	0.0	1.0
1984	27.0	0.0	1.0
1985	27.5	0.0	1.0

*From the "Rulemaking Support Paper," NHTSA, July 1977[7]
**Based on remarks in "Rulemaking Support Paper", NHTSA, July 1977[7]

2.6 Variable Costs Module

The input to this module includes the following information for each manufacturer: material cost per pound (Table 2-11), direct labor cost per car (Table 2-11), and the schedule for implementing the various fuel economy measures. The change in variable cost due to implementing the technological improvements (Table 2-12) is also input to the module. In addition, the outputs from the Marketing and Fuel Economy modules are used by this module to calculate the total variable cost for each manufacturer by year.

TABLE 2-11 MANUFACTURING COSTS DATA

	Material cost per lb.	Labor cost per car
Company G	0.5093	1175.0
Company F	0.715	775.0
Company C	0.8305	1050.0
Company A	0.858	713.0

Source: From "Monthly Progress Report No. 4," HH Aerospace Design Company, Inc., under contract No. DOT-TSC-1333, December 1977.[11]

TABLE 2-12 COSTS RELATED TO FUEL ECONOMY MEASURES

(Nominal Data)

	Capital cost per car	Additional Variable manufacturing cost
Downsizing	1000	*
Material substitution	50	*
Automatic transmission	500	45
Manual transmission	25	25
Lubricants	0	5
Accessories	25	10
Aerodynamic drag	0	10
Rolling resistance	0	35

*Effect on manufacturing costs depends on the weight reduction achieved.

Source: "Rulemaking Support Paper", NHTSA, July 1977[7]

Data regarding the effect of car size on material cost per pound was not available. Nor was it possible to obtain data about the effect of downsizing and material substitution on material cost per pound. After consultation with industry experts and TSC, it was decided to make the following assumptions concerning variable material costs: for a given manufacturer, the material cost per pound is the same for all size-classes of cars, but the material cost per pound is different for different manufacturers. Downsizing does not change the material cost per pound, but material substitution increases the cost per pound by 7 percent.

As for labor costs, once again, the effect of car size on labor costs is not documented. After consultation with industry experts, it was decided to assume that the direct labor cost for a subcompact car is nine-tenths of that of a full-size car, with the other size classes in between.

odule calculates the total variable cost for a manufacturer to be the sum of al costs, direct labor costs, and the additional variable costs for implementing the various fuel economy measures.

2.7 Capital Costs Module

The capital costs module calculates the total capital investment related to fuel economy measures for each manufacturer by year. Fuel economy measures include downsizing, material substitution, and technological improvements in transmission, lubricants, accessories, and aerodynamic drag. The inputs to this module include the schedule for implementing the fuel economy measures for each manufacturer, and the capital cost per car for implementing these measures (Table 2-12). The outputs from the Marketing and Fuel Economy modules are also used.

The module calculates the capital cost of, say, downsizing, by multiplying the number of downsized cars produced by the capital cost of downsizing per car. The justification for this procedure is <u>not</u> that there do not exist economies of scale, but rather that the economies of scale are exhausted before the production levels achieved by any of the manufacturers. The capital costs for any of the measures probably behave as illustrated in Figure 2-2. That is, once the number of cars produced reaches x, the capital cost per car decreases very slowly as the number of cars produced increases. The assumption is that the economies of scale at the margin are not significant for the capacity modifications represented by the model.

DOT, in its reports, assumes that the capital cost per car of implementing any of the fuel economy measures is the same for all manufacturers. This is not really the case since different manufacturers have different degrees of vertical integration. A manufacturer with a low degree of vertical integration will have lower capital costs but higher variable costs of production. Since data on the tradeoff relationship between capital costs and variable production costs is not publicly available, DOT's assumption of equal capital cost per car for all manufacturers was adopted. However, while the results of the model are intepreted, it should be remembered that a manufacturer has the option of reducing capital investment at the expense of increasing the variable cost of production.

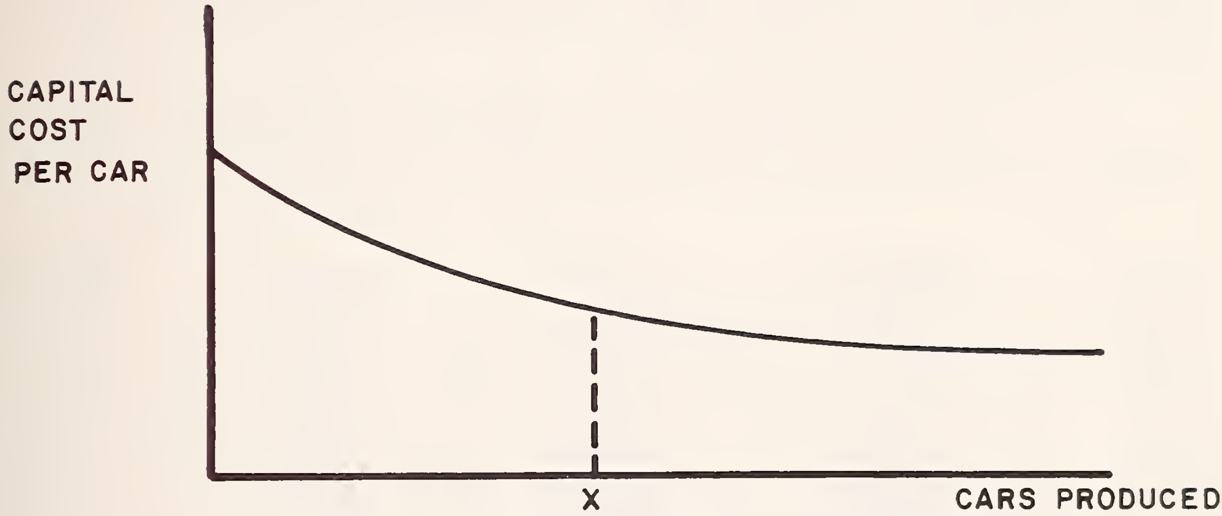

FIGURE 2-2. CAPITAL COST CURVE

2.8 Price Module

The aim of the Price Module is to calculate car prices by size class by year. First, it should be noted that car price means the base sticker price plus the sticker price for options sold on an "average" car in that size class. It is also assumed that the prices by size class are the same for all manufacturers.

Almost all of the concepts, assumptions and data used in this module are adapted from the WEFA model [6]. The central assumption is that the price differential between different size classes is determined by consumer preferences. Consumers prefer a product mix which changes over time, and is determined by various demographic factors (e.g., age distribution of the population, number of families with more than a certain number of children), and economic factors (e.g., income of an average household). The product mix preferred by consumers for the next several years is that predicted by the WEFA model (Table 2-13). If the manufacturers collectively produce a product mix

which is the same as that demanded by the consumers, then the price differential between size classes is as given by the WEFA model. However, if the product mix produced is different from that demanded by the consumers, then the price differential needed to sell this product mix is different and can be calculated using a set of equations contained in the WEFA model. These equations pertain to the price cross-elasticities between size-classes.

TABLE 2-13 PRODUCT MIX DESIRED BY CONSUMERS

(in %)

Year	Full-size	Mid-size	Compact	Subcompact
1976	24.676	30.895	21.065	23.673
1977	30.539	28.284	20.803	22.853
1978	34.329	27.420	19.896	22.470
1979	33.890	25.244	20.966	22.696
1980	33.308	25.363	21.899	21.288
1981	33.696	25.830	22.970	19.605
1982	34.069	25.680	22.710	19.848
1983	34.727	25.815	22.740	19.160
1984	35.397	25.960	22.670	18.570
1985	35.945	25.777	22.388	18.280

Source: The Wharton EFA Automobile Demand Model.[6]

The exact mathematical procedure for using these equations is rather complicated and is explained in detail in Section 3. Here an attempt is made to describe the procedure in brief, intuitive terms. First, however, the concept of "capitalized cost per mile" must be introduced.

A person buying a car will pay, over the life of that car, for items such as: initial price of the car, financing charges, insurance, gas, maintenance, parking and tolls, etc. The discounted present value of all these costs is called the capitalized cost for the car. Similarly, the person will drive the car a certain number of miles per year over the life of the car. The WEFA model calculates the discounted present value of the miles driven by using a "social discount rate." Then dividing the capitalized cost by the discounted present value of miles driven yields the "capitalized cost per mile." It is obvious that the capitalized cost per mile is differnt for different size cars, that larger cars have higher capitalized cost per mile.

It follows from basic economics, that if the capitalized cost per mile for a particular size-class of cars is increased relative to the other size-classes, then the demand for that particular size-class of cars will decrease. The equations from the WEFA model are used to calculate the increase or decrease in the capitalized cost per mile of each size-class car such that the quantity produced is equal to the quantity demanded for each size-class of cars. Given the increase or decrease in the capitalized cost per mile, it is possible to calculate the required price of a new car for each size-class.

One more assumption is needed to make this procedure work. The equations from the WEFA model yield results about price differentials, that is about the price of a new car in a given size-class relative to new car prices for other size-classes. To be able to calculate the price of a new car for each size class, the average car price for each year in the analysis must be estimated.[12] It is assumed that the average car price remains constant over time. That is, if large cars become more expensive, then the small cars will become less expensive. This assuption is congruent with the assumptions made in the WEFA model. The WEFA model assumes that car prices change only because of inflation. Since, in this analysis, inflation is not considered, this is equivalent to assuming that average car prices remain constant over time.

It is also assumed that the increase in manufacturing cost due to other regulatory requirements, say for pollution control and safety, is passed on to the consumer; that is, the car prices are increased by an amount equal to the increase in cost of manufacture due to these regulations. It is also necessary to assume that this increase in car prices

does not decrease the total demand for cars. This assumption is required because of the nature of the WEFA model. The WEFA model considers the average car price as being given exogenously and then projects the total automobile demand assuming this given average car price. While making assumptions about the average car price, it does not consider the impact of government regulation regarding pollution control and safety.

To summarize, the Fuel Economy module calculates the product mix for each manufacturer such that the AFES are met; by aggregating across the manufacturers, the product mix produced by the industry can be obtained. The WEFA model estimates the product mix desired by consumers based on demographic and economic factors. Then, using equations involving price cross-elasticities from the WEFA model, the Price module calculates the new car prices by size-class such that the product mix produced by the industry is just sold.

2.9 Financial Module

The objective of this module is to calculate for each manufacturer various financial line items, such as total capital investment, depreciation, amortization, and dividends paid. Total capital investment is the sum of capital investment related to fuel economy measures, which is calculated by the Capital Costs Module, and other capital investments. It is assumed that "other capital investments" for a manufacturer are constant over time. This assumption is in keeping with the spirit of some of the work done by DOT which assumes that the total capital investment for each manufacturer is constant over time.[13] It would be preferable to use a more sophisticated projection of capital expenditures; however, such projections are not available.

It should be emphasized that financial data in this module pertains only to the U.S. passenger car operations of the automobile companies. Since such data is not released by the companies, the data has been collected from various sources [14, 15, 16, 17 and 18], including DOT reports [13 and 19] and reports sponsored by DOT.[11] In addition, some of the required data was derived from the 10K Reports of the companies.[20]

Assets have been classified into four categories: (1) land and buildings, (2) machinery and equipment, (3) toolings, and (4) other. The "other" category is intended to cover essentially working capital, which is assumed to remain constant over time. Land and buildings and machinery and equiment are depreciated on a straight line basis; while toolings are also amortized on a straight-line basis. In reality, the manufacturers undoubtedly use some form of accelerated depreciation for tax purposes, but straight line depreciation is appropriate for shareholder reporting. In addition, any increase in accuracy that would result from a more complex treatment of depreciation would not be sufficient to warrant the increased complexity.

Liabilities have been classified into equity capital, retained earnings, and long-term debt. As mentioned earlier, equity capital is assumed to remain constant over time. In addition, it is assumed here that dividends are paid on equity capital and remain constant over time; the dividend rate is different for different manufacturers. Interest is charged on long-term debt. If the manufacturer has retired all long-term debt, and has invested in interest bearing securities, then this module calculates the interest earned. In some of the computer reports, investment in securities appears as negative long-term debt. The financial data used to initiate the model is given Table 2-14 and that used for future projections is given in Table 2-15.

TABLE 2-14 FINANCIAL DATA*
(as of December 31, 1976)
(million $)

	Company G	Company F	Company C	Company A
Book value of land and buildings	1639.0	869.0	517.4	43.6
Book value of M/C and equipment	2146.0	1143.8	307.3	80.1
Book value of tooling	391.2	451.2	320.4	20.9
Book value of other assets	3796.0	1923.6	1271.2	197.1
Equity capital	393.8	121.7	233.7	39.2
Debt capital	551.2	726.9	650.5	91.3
Retained earnings	7027.0	3538.8	1514.1	211.4

*For U.S. passenger car operations only.

Source: Derived from 10K Reports issued by the companies.[20]

TABLE 2-15. FINANCIAL DATA
(Used for future projections)
(million $)

	Company G	Company F	Company C	Company A
Annual investment in land and buildings	154.7	31.4	19.3	4.3
Annual investment in M/C and equipment	278.0	87.4	39.4	10.7
Annual investment in tooling	460.0	136.0	72.3	16.0
Depreciation rate for land and buildings	4 %	3 %	3 %	3 %
Depreciation rate for M/C and equipment	8.3	6.66	7.69	7.0
Amortization rate for tooling	50.0	33.3	33.3	25.0
Interest rate on debt capital	7.8	7.8	7.8	7.8
Effective tax rate	46.9	45.6	39.3	30.0
Dividend rate	208.5	111.5	5.0	12.0

Source: Based on 10K Reports issued by the companies.[20]

2.10 Proforma Generator Module

This module takes as input the output from all the previous modules. It calculates the various costs which are usually classified as being fixed costs. Interest, depreciation and amortization are calculated using straight-line depreciation by the Financial module. Retirement and non-income taxes are considered to be fixed for each manufacturer. Selling and Administration, Research and Development, and Maintenance, Repair and Rearrangement are considered to be semi-variable that is, they each have a fixed component, and a variable component which depend on the sales volume. The fixed and variable components were estimated for each company based on historical data using simple regression.

Revenue for a manufacturer is equal to the selling price of the car minus a dealer margin. Income tax is calculated by using an effective tax rate on the net profit before tax figure; the tax rate is different for different manufacturers. If the manufacturer makes a loss, income tax is considered to be negative. This approach was taken for two reasons; First, the "manufacturer" in this analysis is really just a part of a company. Therefore a loss in one division of a company can be used to offset a gain, for tax purposes, in another division. This is equivalent to the loss-making division paying a negative income tax. Second, this assumption simplifies the analysis since it is not necessary to consider carrying forward losses for tax purposes.

This module uses several accounting identities to prepare the followng financial statement: (1) Income statement, (2) Cash Flow statement, (3) Balance sheet. It can also prepare a summary statement which includes only some of the items from the financial statements.

2.11 Assessing Risk

In order to assess the risk along a given dimension, the change in financial performance is observed as the values of the variables describing the given dimension are varied. Economic risk can be assessed by varying the total demand for cars. Marketing risk can be assessed by varying foreign and domestic market shares, foreign product mix, and

price cross-elasticities between size classes. The economic and the marketing uncertainties are the contextual uncertainties.

Technological risk can be assessed by varying the fuel economy gains from the various fuel economy measures, and the impact on fuel economy due to emission control and safety regulations. Risk in manufacturability can be assessed by varying the capital costs, and the increase in variable cost of production due to implementation of the fuel economy measures.

Finally, the financial risk faced by the manufacturer is the synthesis of all the above risks.

In this study all analyses are performed under the assumption that the scenario is defined. Thus the results of the analyses are valid only if the scenario defined reasonably describes the environment. This approach is extremely important since, if the analysis were not conditional on the contextual uncertainty being resolved, the contextual uncertainty would tend to swamp the risk due to having to meet the AFES.

Regarding the endogenous uncertainties (i.e., technological and manufacturability), two alternative approaches are used. In the first approach, fixed values are assumed for all the variables which describe these two dimensions. In these cases, the model is used to estimate the financial performance of each manufacturer under the assumption that the values assigned to these variables are the true values. In the second approach, fixed values are assumed for only some of the variables while, for the rest, it is assumed that only their probability distributions are known. In these cases, the model is used in a Monte Carlo simulation to derive risk profiles for each of the manufacturers. For the probability case, the model has the capacity to handle truncated Normal distributions and Uniform distributions. The model produces risk profiles for four different summary measures of performance: (1) after-tax profit, (2) retained income, (3) long-term debt, (4) fuel economy without mix shifts. All four summary measures reported are for the last year of the period under analysis. A more detailed description of the method for obtaining the risk profiles is given in Section 3.

A typical line from the risk profile calculated by the model looks like:

	Fractiles				
	0.10	0.25	0.50	0.75	0.90
After-tax Profit (Billion $)	1.0	1.3	1.8	1.9	2.0

This is to be interpreted as follows: there is a 0.1 chance that the profit will be less than or equal to $1.0 billion; a 0.25 chance that it will be less than or equal to $1.3 billion; a 0.5 chance that it will be less than or equal to $1.8 billion; and so on. Similarly, it can be inferred that there is a 0.5 chance that the profit will be between $1.3 billion and $1.9 billion and a 0.8 chance that it will be between $1.0 billion and $2.0 billion.

3. DETAILED DESCRIPTION OF THE AFES MODEL

3.1 General

In this section, a detailed description of the model is given. The model determines the performance of each manufacturer, given all the required data, for one year at a time. Starting with the first year in the period under analysis, the model progresses forward in time, calculating the performance for each manufacturer for each year in the period under analysis.

A detailed description of the modules which constitute the model is given below. The description given is for determining the performance of each manufacturer for one year only. The method for determining the manufacturers' performance for several years is a straightforward extension of the description given below.

3.2 Marketing Module

The inputs to this module are the total U.S. demand, the foreign market share and the market shares of each of the four domestic manufacturers. The module calculates the sales volume for the foreign manufacturers and each of the domestic manufacturers. The mathematical equations are:

s_j = market share of domestic manufacturer, j

s_f = foreign market share

D = total U.S. demand

S_j = sales volume of domestic manufacturer, j

S_f = sales volume of foreign manufacturers

$$S_f = s_f \, . \, D$$

$$S_j = s_j \, . \, (1 - s_f) \, . \, D$$

It is assumed that s_j is constant over time while s_f and D vary over time. Actually, s_j is a function of several factors including the manufacturers' performance in the recent past. Since such a relationship is extremely difficult to formulate quantitatively, some simplifying assumption about the behavior of s_j over time is essential.

3.3 Fuel Economy Module

The aim of this module is to calculate the product mix produced by each manufacturer. Since the product mix produced by any manufacturer has no effect on the product mix produced by the other manufacturers, the procedure is described for just one manufacturer. First, the fuel economy by size-class is calculated considering the effect of weight reduction measures such as downsizing and material substitution (see Tables 3-1 to 3-3). Let

w_k = curb weight of car in size-class k

w'_k = curb weight of car in size-class k in 1977

e_k = fuel economy of car in size-class k

e'_k = fuel economy of car in size-class k in 1977

TABLE 3-1 CURB WEIGHT
(in lbs.)

(Year 1977)

	Full-size	Mid-size	Compact	Subcompact
Company G	4158	4073	3395	2587
Company F	4675	4217	3274	2508
Company C	4564	4184	3556	2200
Company A	-	4107	3331	2970

Source: "Data Analysis for 1981-1984," Document 2, Vol. I.[7]

TABLE 3-2 CURB WEIGHT AFTER DOWNSIZING

(in lbs.)

	Full-size	Mid-size	Compact	Subcompact
Company G	4158	3345	2838	2229
Company F	3837	3525	2899	2192
Company C	3911	3547	2956	2200
Company A	-	3439	2864	2000

Source: "Data Analysis for 1981-1984," Document 2, Vol. I.[7]

TABLE 3-3 CURB WEIGHT AFTER MATERIAL SUBSTITUTION
(in lbs.)

	Full-size	Mid-size	Compact	Subcompact
Company G	3645	3118	2629	2123
Company F	3556	3280	2673	2077
Company C	3661	3286	2956	2050
Company A	-	3239	2549	2000

Source: "Data Analysis for 1981-1984," Document 2, Vol. I.[7]

Then e_k and e'_k are related as follows:

$$e_k = e'_k \left[\frac{0.575}{\left[\dfrac{w_k + 300}{w'_k + 300}\right]^{0.471}} + \frac{0.425}{\left[\dfrac{w_k + 300}{w'_k + 300}\right]^{0.320}} \right]$$

This equation is an approximation based on two equations in the WEFA model which give the relation between fuel economy and various characteristics of a car including the car's inertia weight.

Next, the fleet weighted average fuel economy is calculated for the manufacturer considering the effect of the technological improvements on fuel economy, the penetration of the technological improvements, and the effect of the emission control and safety regulations. To do this, the previous year's product mix is used.

a = fleet weighted average fuel economy using previous year's product mix

c'_k = proportion of cars of size-class k produced in the previous year

g_i = fuel economy gain due to technological improvement i

p_i = penetration of technological improvement i

P_e = decrease in fuel economy due to emission control regulations

P_s = decrease in fuel economy due to safety regulations

$$a = \left(\sum_k c'_k \cdot e_k\right)\left(1 + \sum_i g_i \cdot p_i\right)\left(1 - P_e - P_s\right)$$

If the fleet weighted average fuel economy using the previous year's product mix is greater than the AFES, then the new product mix is the same as the previous year's.

A = the automobile fuel economy standard

c_k = proportion of cars of size-class k produced in the year under consideration.

If $a \geq A$, then $c_k = c'_k$.

However, if the fleet weighted average fuel economy using the previous year's product mix is less than the AFES, then the product mix is changed. The product mix is changed in such a manner that the proportion of cars shifted from a size-class to the next smaller size-class is the same for all size-classes.

This concept is illustrated by an example. The first line in Table 3-4 gives the product mix in the previous year for a manufacturer. Assume that a 10 percent shift in the product mix is needed to satisfy the AFES. Therefore, 10 percent of the consumers in each size-class shift away from the size-class to the next smaller size-class. The second row in Table 3-4 gives the proportional shift away from each size-class; it may be noted that this proportion is zero for the subcompact class since there is no smaller size-class than the subcompact. Proportional shift away from a size-class is equal to 10 percent of the product mix in the previous year; except, of course, for the subcompact class. Proportional shift to a size-class (see the third row in Table 3-4) is equal to the proportional shift away from the next larger size-class. The proportional shift to the full-size class is, of course, zero since there is no larger size-class. Finally, the product mix in the current year is equal to the product mix in the previous year minus the shift away from a size class plus the shift to a size class.

TABLE 3-4 PRODUCT MIX CHANGE

	Full-size	Mid-size	Compact	Subcompact
Product mix in previous year	0.10	0.30	0.40	0.20
Shift away from a size-class	0.01	0.03	0.04	0.00
Shift to a size class	0.00	0.01	0.03	0.04
Product mix in current year	0.09	0.28	0.39	0.24

If size-class 1 is full-size, size-class 2 is mid-size, and so on, and x is their proportional shift in the product mix, then:

$$c_1 = (1 - x)c_1'$$

$$c_2 = xc_1' + (1 - x)c_2'$$

$$c_3 = xc_2' + (1 - x)c_3'$$

$$c_4 = c_4' + xc_3'$$

$$A = (\sum_k c_k \cdot e_k)(1 = \sum_i g_i \cdot p_i)(1 - p_e - p_s)$$

Thus, there are five equations in five unknowns, and the equations can be solved to obtain the new product mix, i.e., c_k, $k = 1, 2, 3, 4$.

3.4 Variable Manufacturing Costs Module

Since the variable manufacturing costs for any manufacturer have no effect on the costs for other manufacturers, the equations contained in this module are described for just one manufacturer.

m = material cost per pound in 1976

l = direct labor cost per car in 1976

o_i = variable cost per car for implementing technological improvement i

m_k = material cost per pound for car in size-class k in the year under consideration

S = total sales volume for the manufacturer

Then m_k = m if material substitution has not been implemented for size-class k, and m_k = 1.074m if material substitution has been implemented for size-class k.[21]

$$\text{Total material cost} = \left(\sum_k m_k \cdot c_k \right) \cdot S$$

$$\text{Total direct labor cost} = (1.05c_1 + 1.02c_2 + 0.99c_3 + 0.95c_4) \cdot 1 \cdot S$$

$$\begin{array}{l}\text{Additional variable cost} \\ \text{of the technological improvements} = \left(\sum_i o_i \cdot p_i \right) \cdot S\end{array}$$

The total variable cost of production is equal to the sum of the material cost, direct labor cost, and the additional variable cost of the technological improvements.

The parameters m, l and p_i are different for different manufacturers. But, since DOT assumes that the cost of implementing the technological improvements is the same for all manufacturers, the parameters o_i are the same for all manufacturers.

3.5 Capital Costs Module

The aim of this module is to calculate the capital costs related to the fuel economy measures for each manufacturer; the fuel economy measures are: downsizing, material substitution, and technological improvements. Since these capital costs for one manufacturer do not affect the costs for other manufacturers, the module is described for only one manufacturer.

C_o = capital cost of implementing the technological improvements

k_i = capital cost per car of implementing technological improvement i

S = sales (in units) for manufacturer in year under consideration

S' = sales (in units) for previous year

p_i = penetration of technological improvement i in year under consideration

p'_i = penetration of technological improvement i in previous year

$$C_o = \sum_i (p_i \cdot S - p'_i \cdot S') \cdot k_i$$

In order to calculate the capital cost of downsizing, a dummy variable d_k must be defined. Let the year under consideration be year T. Then define d_k as:

$$dk = \begin{cases} O & \text{If size-class k has not been downsized before or in year T} \\ c_k \cdot S & \text{if size-class k is being downsized in year T} \\ (c_k \cdot S - c'_k \cdot S') & \text{if size-class k was downsized before year T, i.e., in year (T - 1) or before} \end{cases}$$

Then C_d, the capital cost of downsizing for year T, is given by

$$C_d = \sum_k d_k \cdot K$$

where K = capital cost per car of downsizing.

The calculation of capital cost for material substitution is identical to that for downsizing. Let C_m be the capital cost of material substitution in year T. Then the total capital cost in year T related to fuel economy measures is = $C_o + C_d + C_m$.

3.6 Price Module

The objective of this module is to calculate the new car prices by size-class. It is assumed that for a given size-class, all manufacturers receive the same price per car. The basic assumption in this module is that the price differentials between size classes are determind by the interaction between the product mix supplied by the industry and the consumer preferences via a price-clearing mechanism. It is thus impossible to consider one manufacturer at a time; rather, it is necessary to take into account the product mix produced by each manufacturer simultaneously. The product mix supplied in the market given each manufacturer's product mix is calculated first.

f_k = proportion of cars of size-class k produced by foreign manufacturers

y_k = proportion of cars of size-class k supplied in the market

c_k^j = proportion of cars of size-class k produced by manufacturer j

$$y_k = f_k \bullet s_f + \sum_j (1 - s_f) \bullet s_j \bullet c_k^j$$

In order to use the equations involving price cross-elasticities given in the WEFA model, "capitalized costs per mile," as defined in the WEFA model, must be used. A detailed description of this concept can be found in the report on the WEFA model[6]. Here, the concept is described only briefly. A person buying a car will over the life of that car pay for items such as: initial price of the car, financing charges, insurance, gas, maintenance, parking and tolls, etc. The discounted present value of all these costs is called the capitalized cost for the car. Using a special discount rate, the discounted present values of miles driven can be obtained. The ratio of the above two discounted values is called the "capitalized cost per mile." Obviously, the capitalized cost per mile is different for different size-class cars.

In this context, the realtionship between the price of a new car and the capitalized cost per mile is required. Using the data and assumptions from the WEFA model, the following equations can be derived:

$$a_1 = 0.14049 + 6014w_1$$

$$a_2 = 0.13367 + 5316w_2$$

$$a_3 = 0.12439 + 4399w_3$$

$$a_4 = 0.10761 + 3887w_4$$

where,

a_k = capitalized cost per mile for size-class k (size-class 1 is full-size, size-class 2 is mid-size, and so on)

w_k = price of a new car is size-class k

The following four equations are derived from the WEFA model:

$$\frac{cy_1}{1 - cy_1} = \beta_1 \left\{ \frac{a_1}{\dfrac{a_2y_2 + a_3y_3 + a_4y_4}{y_2 + y_3 + y_4}} \right\}^{-8.84702}$$

$$\frac{cy_2}{1 - cy_1} = \beta_2 \left\{ \frac{a_2}{\dfrac{a_1y_1 + a_3y_3 + a_4y_4}{y_1 + y_3 + y_4}} \right\}^{-1.98095}$$

$$\frac{cy_3 + cy_4}{1 - cy_3 - cy_4} = \beta_3 \left\{ \frac{\dfrac{a_3y_3 + a_4y_4}{y_3 + y_4}}{\dfrac{a_1y_1 + a_2y_2}{y_1 + y_2}} \right\}^{-2.75703}$$

$$\frac{y_4}{y_3} = \beta_4 \left\{ \frac{a_4}{a_3} \right\}^{-11.9101}$$

where c, β_1, β_2, β_3 and β_4 are some constants.

The WEFA model uses these four equations differently than this analysis. In the WEFA model, β_1, β_2, β_3, and β_4 are determined by various demographic and economic factors, and, in the present context, are known. The costs a_1, a_2, a_3 and a_4 are also assumed to be known. The WEFA model is then aimed at determining the desired product mix: y_1, y_2, y_3, and y_4. (Actually, since c is also unknown, one more equation is needed. The fifth equation used is a normalizing equation: $y_1 + y_2 + y_3 + y_4 = 1$.)

However, in this analysis y_1, y_2, y_3, and y_4 are known, since they constitute the product mix supplied in the market. The capitalized costs per mile, a_1, a_2, a_3, and a_4, need to be determined. Another difference is that in the WEFA model, y_k are actually shares of the total stock of cars, while here, y_k is shares of new car registrations. However, that is a reasonably good approximation.

First, from the results of the WEFA model for the year under consideration, the desired mix is obtained, as well as the capitalized cost per mile (associated with this desired mix) by size class. Using this data, β_1, β_2, β_3 and β_4 can easily be calculated in the above equations.

Now, the equations are used in the analysis. The values of y_1, y_2, y_3, and y_4 are found by aggregating the product mix for each manufacturer using the equation given earlier in this module. There are four, nonlinear, simultaneous equations in five unknowns: a_1, a_2, a_3, a_4 and c.

In order to obtain a single solution, a_4 is arbitrarily fixed to be the same value as the capitalized cost per mile for size-class 4 in the WEFA model. This approach is for computational reasons only and ultimately the new car price will be normalized such that the average car price is constant over time rather than a_4.

After a_4 is arbitrarily fixed, four nonlinear equations in four unknowns remain. A search method is used for solving these equations. It is expected that it has a value near 1.0. A search for c is conducted over the range 0.7 to 1.4 to obtain a solution to the four equations. The search is carried out in two stages. First, there is a search over the range 0.7 to 1.4, and c is incremented by 0.1 at each step. Suppose that from this search it is found that 0.9 is the best value for c. Then there is a search for c in the range 0.8 to 1.0, and c is incremented by 0.01 at each step. Thus, the procedure for

solving the four nonlinear equations is quite accurate. The values of a_1, a_2, a_3 and c, in addition to a_4, are now known.

When the equations relating price of a new car to its capitalized cost per mile are used, the new car prices, w'_1, w'_2, w'_3 and w'_4 are obtained. These prices must now be normalized such that the average price is constant over time. If:

w_k = new car prices, which are the output of this module

w'_k = unnormalized new car prices (obtained above)

A = average price per car (which is constant over time)

Then:

$$\frac{w_k}{w'_k} = \text{constant}$$

$$\sum_k y_k \cdot w_k = A$$

Using the above equations the new car prices are obtained which satisfy the two conditions: (1) average car price remains constant over time, and (2) the price differential between size-classes is such that the product mix supplied to the market is just sold. That is, at this price differential, the consumers demand a product mix which is identical to the one actually supplied.

3.7 Financial Module

Capital assets are divided into four classes: (1) land and buildings, (2) machinery and equipment, (3) tooling and (4) other. The "other" capital assets remain constant over time since there is no additional investment or depreciation for this class of capital asset. This module keeps track of the book value of the first three classes of capital

assets. It is assumed that of the fuel economy related capital investment (which is the output from the Capital Cost module), 5 percent goes into land and buildings, 35 percent into machinery and equipment and 60 percent into tooling. Besides the fuel economy related capital investment in each of these three categories of investment, it is assumed that there is a constant annual capital investment in each of these three categories of investment. The capital assets (except for "other" capital assets) are depreciated on a straight line basis; the rate of depreciation is different for the different categories. For a given category, the rate of depreciation is different for different manufacturers. Then, for a given class of capital investment, the new book value is equal to the book value in the previous year plus the investment in this year, and minus the depreciation.

Interest is calculated on the outstanding long-term debt using a constant rate of interest; the rate of interest may be different for different manufacturers. Dividend paid out is calculated on the equity capital using a constant rate. Since, by assumption, the equity capital is constant, the dividend paid is constant for each manufacturer over time. The dividend rate may be different for different manufacturers.

3.8 Proforma Generator Module

The aim of this module is to generate the income statement, the cash flow statement and the balance sheet for each manufacturer. Since the financial statements for a manufacturer can be generated without considering the other manufacturers, the module is described with respect to just one manufacturer.

z_k = dealer's margin for a car in size-class k

c_k = proportion of cars of size-class k produced by the manufacturer

w_k = new car price for size-class k (determined by the Price module)

S = sales volume of the manufacturer

$$\text{Revenue} = \left[\sum_k c_k \cdot w_k(1 - z_k)\right] \cdot S$$

Next, the module calculates the "fixed costs." However, this is somewhat of a misnomer since not all "fixed costs" are really fixed: some are semi-variable, some are calculated for each year and the rest are fixed. Selling and General Administration, Research and Development, and Maintenance, Repair and Rearrangement are semi-variable; that is, they have a fixed component and a component which is proportional to revenue. Interest, depreciation and amortization are calculated for each year by the Financial module. Retirement fund and non-income tax costs are fixed and remain constant over time.

Before-tax profit is calculated as revenue minus variable costs of production minus the fixed costs. Finally, income tax is calculated using an effective rate of taxation, which is constant over time.

The cash flow statement and the balance sheet are generated using the information calculated thus far and the usual straightforward accounting identities. The sources of cash are net after-tax profit, depreciation, and amortization. The uses of cash are the total capital investments made (in that particular year) and dividends paid. The difference between the sources and uses of cash gives the net cash inflow. The net cash inflow is used to retire long-term debt. If the net cash inflow is negative, then the long-term debt is increased.

In the balance sheet, the book values of the four classes of assets are obtained from the Financial Module. The liabilities are: equity capital, long-term debt and retained earnings. By assumption, the equity capital is held constant. Long-term debt is equal to the long-term debt in the previous year minus the decrease in long-term debt (which is equal to the net cash inflow). The retained earnings are equal to the retained earnings in the previous year plus the net after-tax profit in the current year minus the dividends paid.

3.9 Use of the Model to Generate Risk Profiles

In the equations used in the model described above, it is assumed that all the variables and parameters are known with certainty. However, actually, all the parameters are not known with certainty. In particular, there is uncertainty connected with the fuel economy related parameters: the capital cost per car for downsizing, material substitution and the technological improvements, additional variable costs for the technological improvements, and the fuel economy gains from the technological improvements. Suppose that instead of the above being known, only a probability distribution for each parameter is known. Further, it is assumed that these probability distributions are independent of one another.

One way to approach such a situation is to analytically determine the probability distributions for the output variables of the model. However, given the complexity of the model, this approach is impossible to implement. Another, and more feasible approach is to use Monte Carlo simulation.

The procedure is described with respect to just one random variable. Since it is assumed that the random variables are independently distributed, it is possible to repeat for each of the random variables, the procedure to be described for one random variable at a time. Let the random variable be, say, the capital cost per car for downsizing, K. (The tilde on the variable is to denote that the variable is a random variable.) It is assumed that a density function f(K) for the variable K is known.

A random number generator is used to determine a value of K according to the probability density function f(K). Say that it generates the number 1125. This number, 1125, then becomes the capital cost per car of downsizing. Similarly, the values of the other random variables are generated. The performance of each manufacturer is determined by using these values and the model. This constitutes one trial in the Monte Carlo simulation. To get a probability distribution of the performance of each manufacturer, the procedure of generating values of the random variables is repeated, and the model is used to determine the performance with those values, by taking several trials in the simulation.

If the performance is measured by the financial statements over time, the probability distributions obtained would be very complex multivariate distributions. Therefore, attention must be concentrated on a few summary measures of performance. In this analysis, after-tax profit, long-term debt, retained income, and fuel economy without mix shifts, all in the last year of the period under analysis, are routinely given. In the output of the model, the probability distribution is represented by the values of five standard fractiles: the 0.1, 0.25, 0.5, 0.75, and 0.9 fractiles.

The model, as it is programmed now, can handle two types of probability distributions: truncated normal distribution and uniform distribution. The uniform distribution is specified by two parameters: the minimum value and the maximum value as given in Figure 3-1.

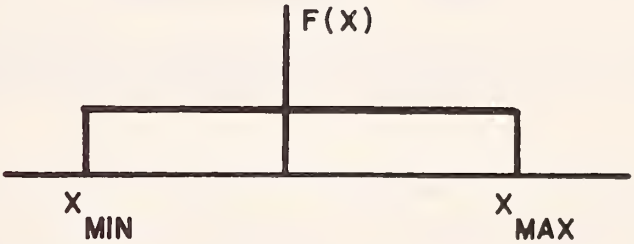

FIGURE 3-1. UNIFORM DISTRIBUTION BY MINIMUM AND MAXIMUM VALUE

A truncated normal distribution is depicted in Figure 3-2 in dark lines. Four parameters are needed to specify a truncated normal distribution: the minimum value, the maximum value, the mode (i.e., the most likely value), and the standard deviation of the normal distribution. (Note that the standard deviation of the normal distribution is greater than the standard deviation of the truncated normal distribution.) In a truncated normal distribution, the area from the tails is distributed proportionally over the range of the distribution, that is, between the minimum and maximum values. If the minimum and maximum values are the same for a uniform distribution and a truncated normal distribution, then the uniform distribution is more dispersed. In other words, the uniform distribution has a higher variance than the truncated normal distribution. This results in the distribution of the performance measures having a larger variance also.

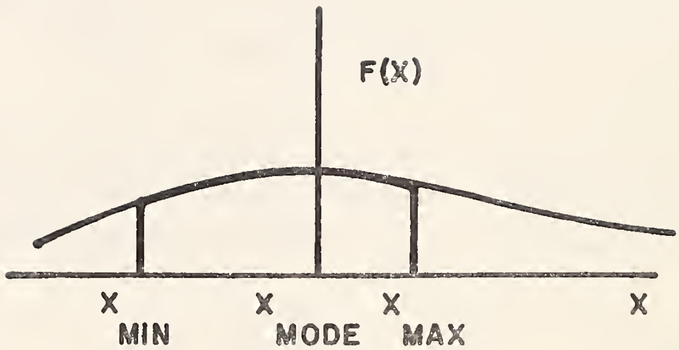

FIGURE 3-2. TRUNCATED NORMAL DISTRIBUTION

4. NOMINAL SCENARIO

4.1 General

In this section, the nominal scenario is analyzed. "Nominal" means that the one-point estimates generated by DOT are used. It may be noted that all the data in DOT reports is in the form of one-point estimates. Nominal scenario means that all the data, except the data related to fuel economy measures, is set at nominal values or most likely values. Within the nominal scenario, four cases are examined. In the first case, the Nominal case, nominal data is used for the fuel economy related variables also. The next two cases use optimistic and pessimistic values for the fuel economy related variables. In the fourth case, it is assumed that the fuel economy related variables are uncertain and that there are probability distributions for them.

In the above analysis the joint impact of technological and manufacturing uncertainty is assessed. In the last part of this section the impact of technological uncertainty is separated from that of manufacturing uncertainty.

4.2 Nominal Case

The computer printed results for this case are given in Appendix A. However, the detailed financial statements for each year have not been included in order to save space. Here the results are presented in graphical and tabular form and some comments are offered about them.

Figure 4.1 indicates the fuel economy achieved by the four manufacturers if they implemented all the fuel economy measures as per the schedules assumed, but maintained their product mixes the same as those in 1976. None of the manufacturers will be able to meet the AFES after 1981 without changing the product mix. Thus, the manufacturers have to produce more small cars and fewer of the larger cars. This can be seen by comparing the mix produced in 1985 with that produced in 1977 (see Table 4-1). The effect of this on the price differential between size-classes would be to make

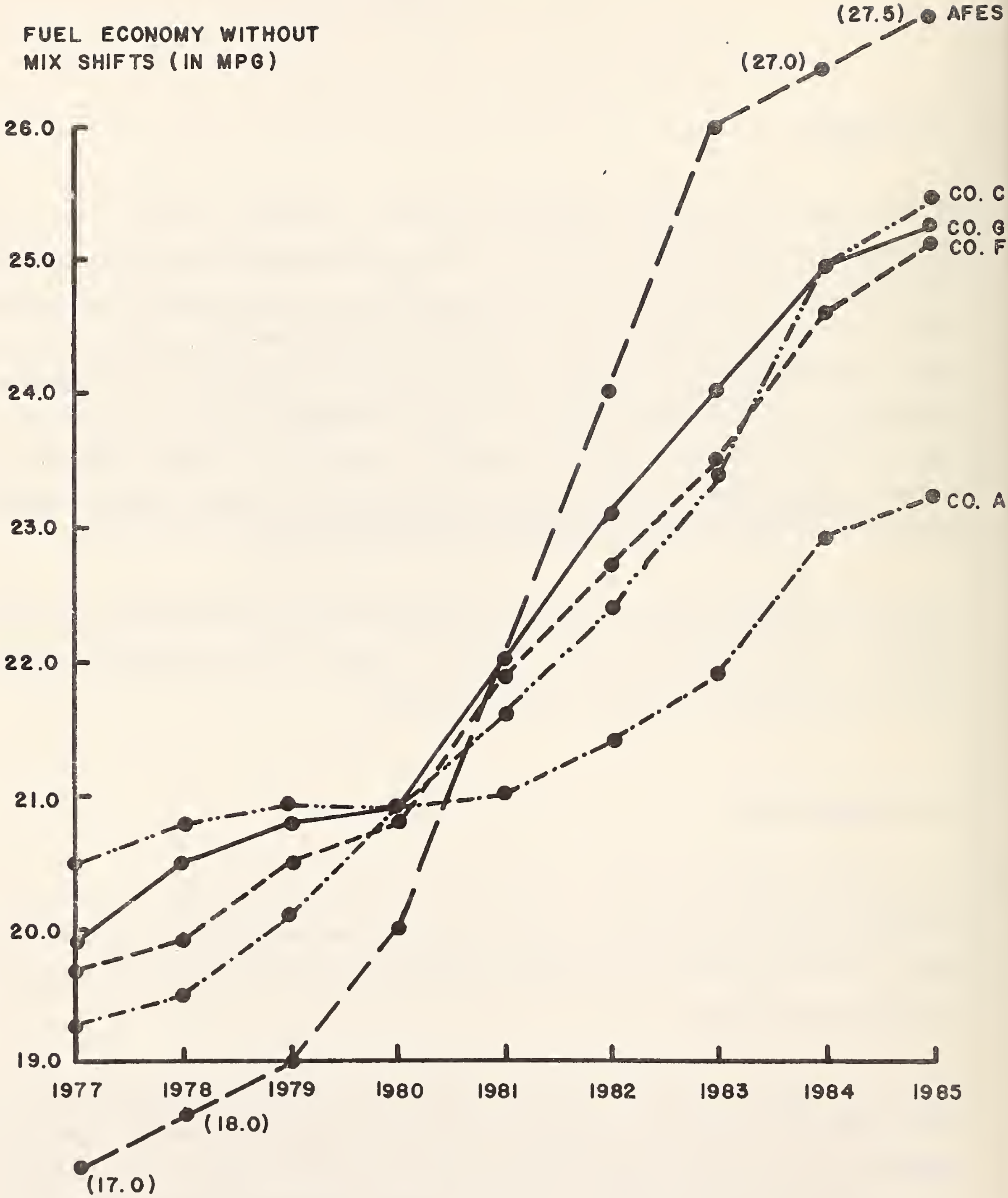

FIGURE 4-1. NOMINAL CASE - FUEL ECONOMY ACHIEVED WITHOUT MIX SHIFTS

the larger cars more expensive and the smaller ones less expensive.

This effect is reinforced by the changing consumer preferences. By comparing the mix desired in 1985 with that in 1977, it is seen that consumers prefer a larger proportion of the larger cars in 1985 than in 1977. This change is due to the changes in the demographic characteristics of the population. For example, the average age of the population is higher in 1985 than in 1977, and since older people tend to prefer larger cars, a larger proportion of larger cars is desired in 1985 than in 1977. Thus, the two factors, change in mix produced (induced by AFES), and change in mix desired (induced by demographic changes), both have the same effect on car prices: the larger cars become more expensive and the smaller ones less expensive. The results of the model indicate that this indeed does happen, as can be seen by comparing the prices in 1985 with those in 1977 (see Table 4-1). The behavior of the car prices over the period 1977-85 is represented in Figure 4-2.

TABLE 4-1 NOMINAL CASE MARKET CHARACTERISTICS

	Full-size	Mid-size	Compact	Subcompact
Mix produced in 1977	0.19	0.27	0.23	0.32
Mix produced in 1985	0.11	0.23	0.25	0.40
Mix desired in 1977	0.31	0.28	0.20	0.23
Mix desired in 1985	0.36	0.26	0.22	0.18
Price in 1977	7924	6315	4747	3866
Price in 1985	9569	7184	4947	3689

The difference between the number of full-size cars desired and actually produced as a fraction of the total demand is the fraction of consumers who have switched from a full-size car to a smaller car due to the changed price differential between the size classes. Similarly, the difference between the number of subcompact cars desired and actually produced as a fraction of the total demand is the fraction of consumers who

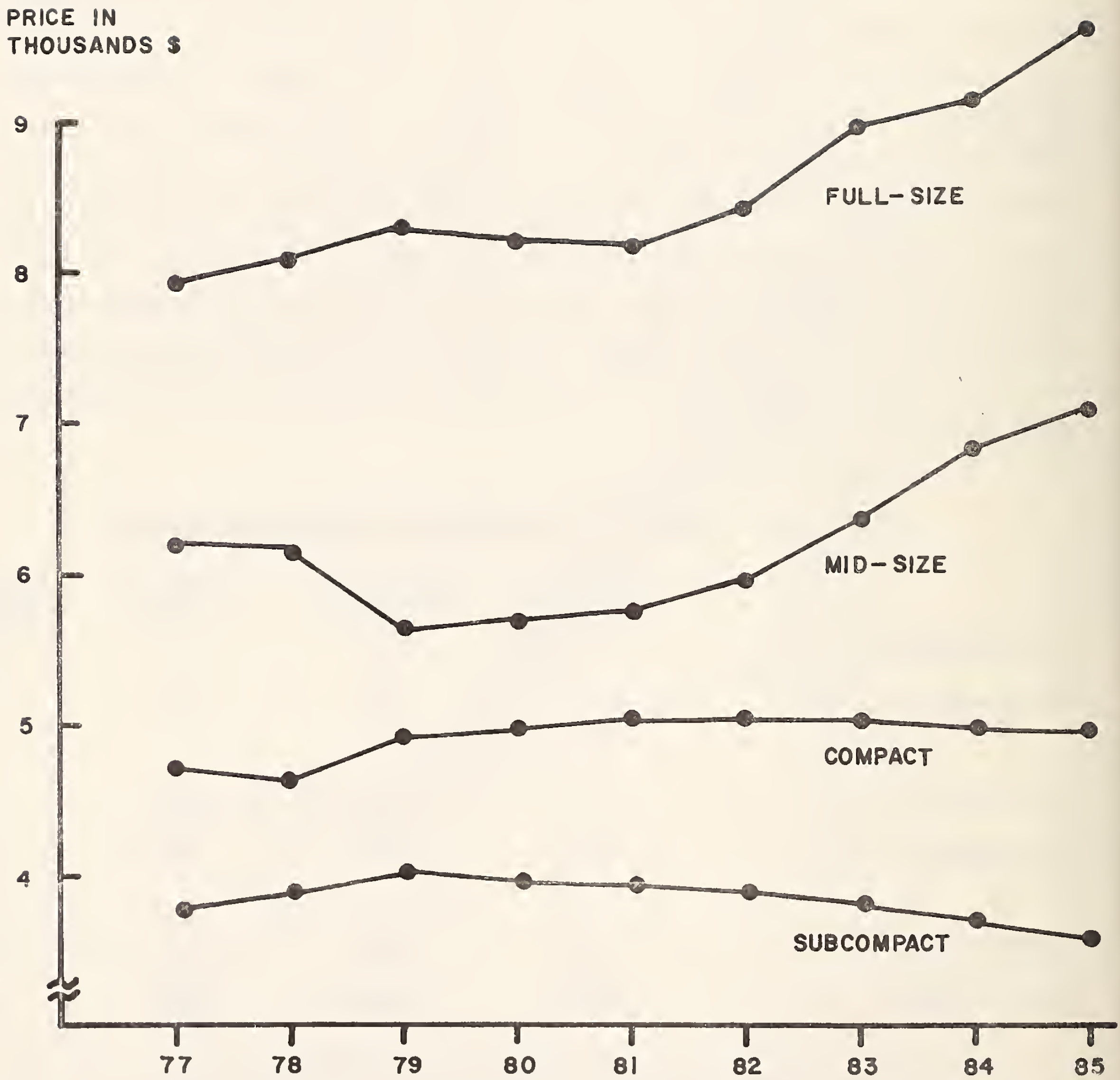

FIGURE 4-2. CAR PRICES BY SIZE CLASS

have switched from a subcompact car to a larger car. Since the number of subcompact cars demanded is less than actually produced, this fraction is negative. Figure 4-3 depicts the behavior of these two fractions over the period 1977-85.

Figure 4-4 gives the after-tax profit and the net cash inflow for each of the four manufacturers for the period 1977-85. Under the assumptions made in the model, Company G performs very well: its after-tax profits and net cash inflow are positive throughout the period and increase steadily. Company F performs well with increasing after-tax profit and positive cash inflows except for one year, 1979. Company C, however, makes a loss almost throughout the period, though its losses decrease fairly steadily. In 1985 it does make a slight profit; its return on sales is less than 1 percent (see Table 4-2). Its cash inflows are significantly negative throoughout the period, except for a small postitive inflow in 1985. From this it would seem that Company C has to find some way of raising significant amounts of capital; Company C would probably reduce the amount of capital required by reducing investment (i.e., reducing with respect to the assumptions made in this model). Company A fares even worse, making significant losses throughout the period 1977-85. Unlike Company C, Company A exhibits no trend towards profitability. Its cash inflows are significantly negative throughout this period.

From the return on sales in 1985 (see Table 4-2) it can be seen that Company G and Company F are both in very healthy positions; both have generated significant amounts of cash (since their long-term debt is negative) which must have been invested elsewhere by these corporations. Company C has a debt/equity ratio of 3.0 which is clearly impossible, considering industry practice. Even if Company C does not need as much capital as predicted by this model, it seems that it would still have to raise significant amounts of capital. From the capital structure predicted by the model, it appears that Company C would have to raise at least some equity capital of some form or another. As for Company A, the capital structure predicted is clearly an untenable position. Retained earnings are negative, that is, the stockholders' equity is negative; long-term debt is very high. It is extremely unlikely that Company A would ever actually achieve such a position. What would undoubtedly happen is that before 1985, Company A would have to take some actions to raise equity capital in some form or another, cut down on investments and losses, sell other assets, or close down operations.

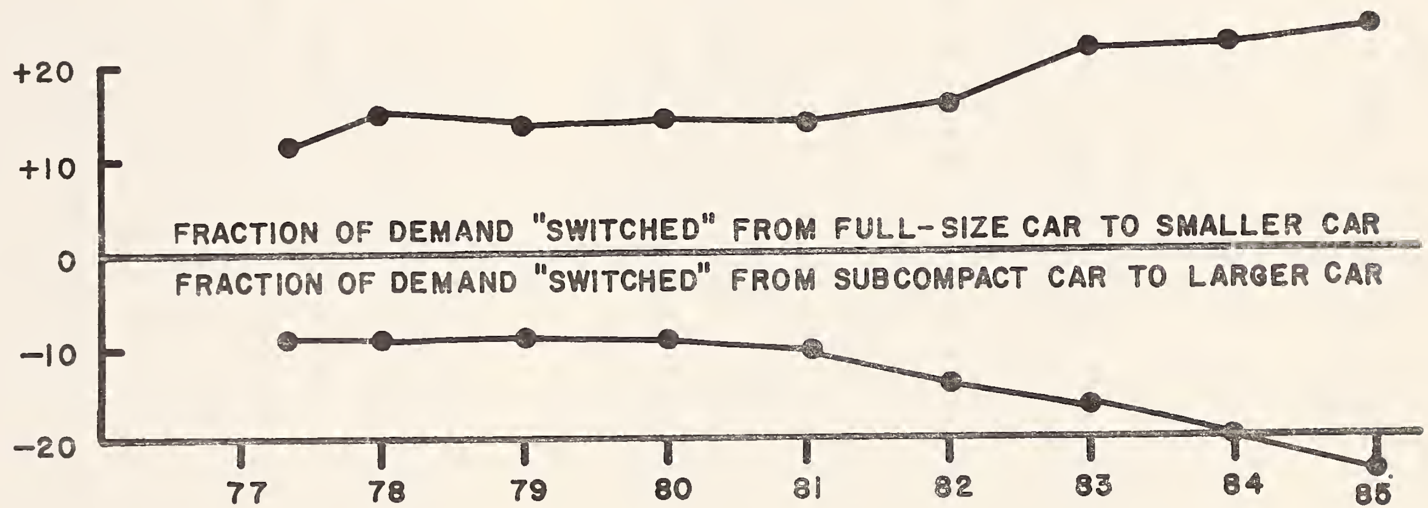

FIGURE 4-3. MARKET INDUCED SWITCHING IN CONSUMER BEHAVIOR

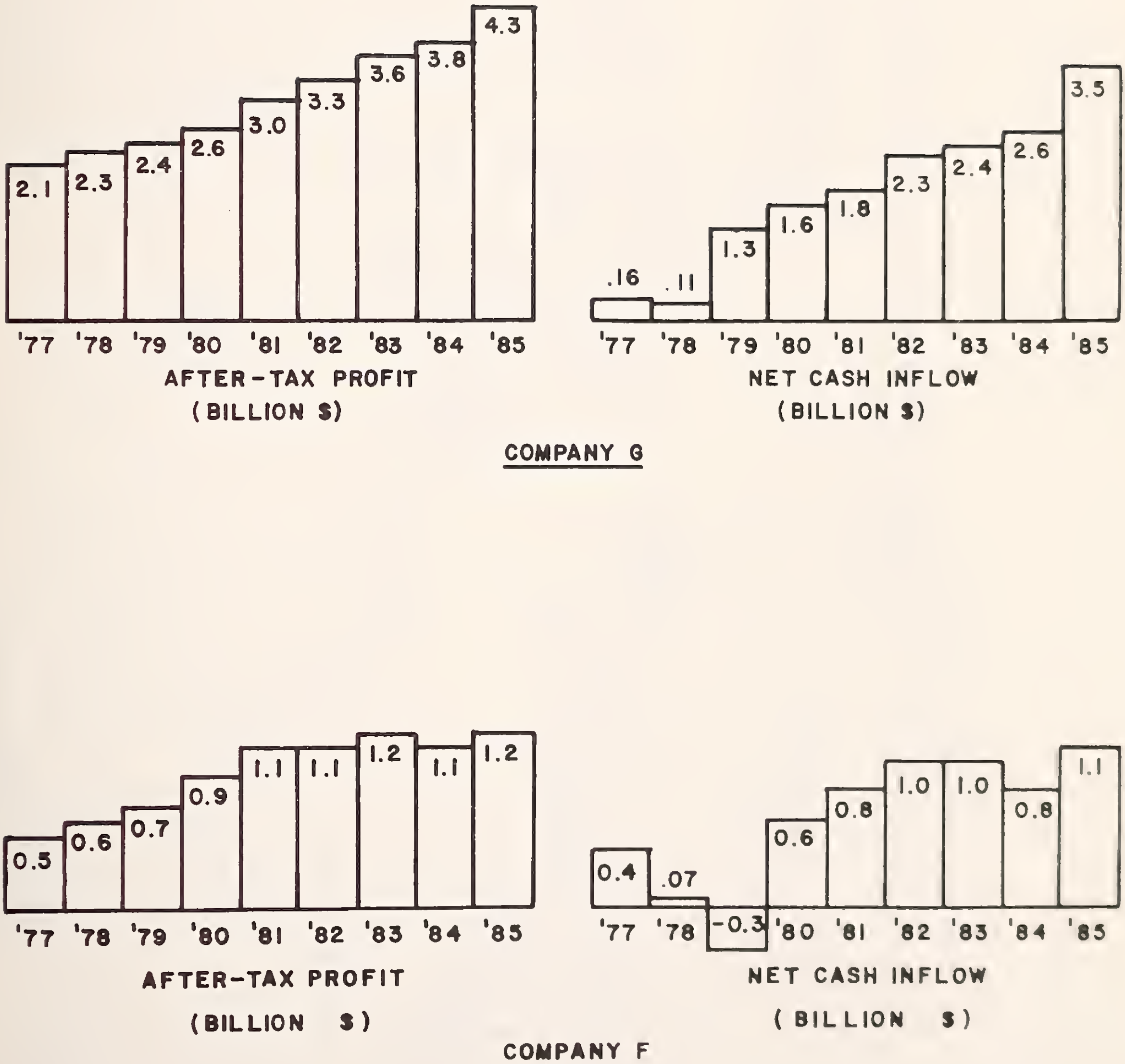

FIGURE 4-4. NOMINAL CASE RESULTS—FINANCIAL PERFORMANCE 1977-1985 (SHEET 1 OF 3)

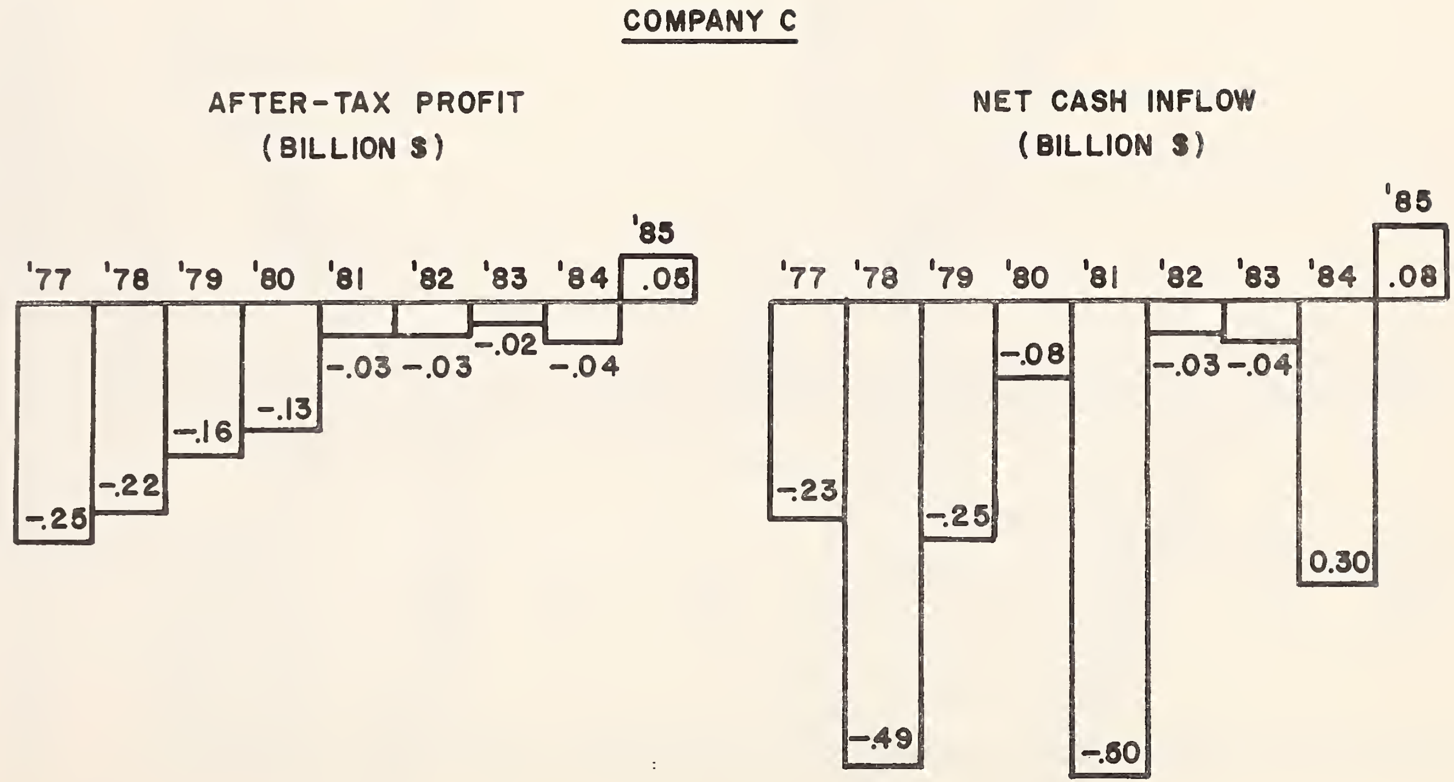

FIGURE 4-4. NOMINAL CASE RESULTS - FINANCIAL PERFORMANCE 1977-1985 (SHEET 2 OF 3)

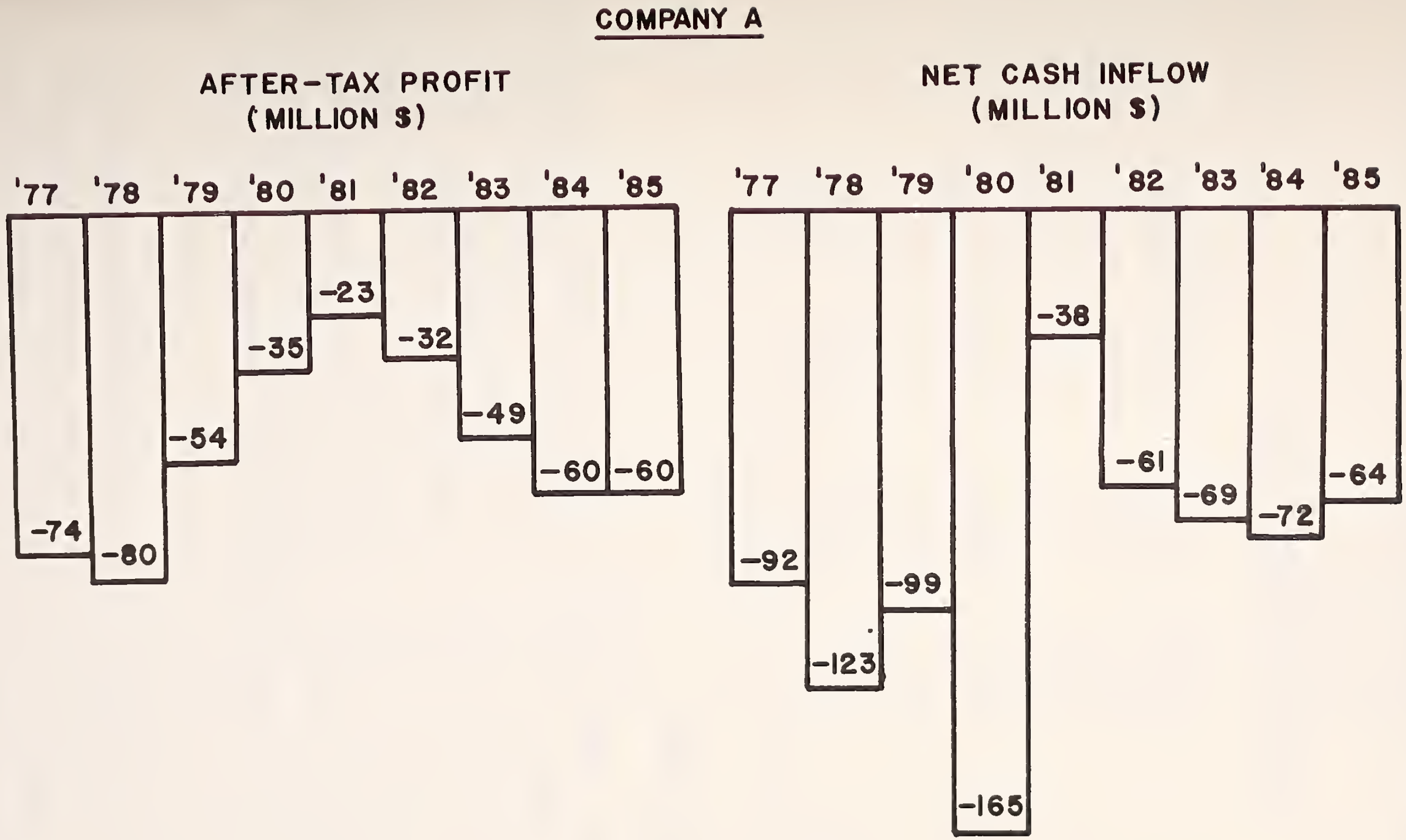

FIGURE 4—4. NOMINAL CASE RESULTS— FINANCIAL PERFORMANCE 1977-1985 (SHEET 3 OF 3)

It is not possible to use the model to predict what action Company A will take; but the model does indicate that some drastic action will be essential.

TABLE 4-2. NOMINAL CASE
FINANCIAL POSITION 1985

	Company G	Company F	Company C	Company A
Sales (million cars)	5.9	2.7	1.6	0.25
Breakeven (million cars)	2.7	1.4	1.5	0.35
Revenue (billion $)	29.9	11.9	7.2	0.87
After-tax profit (billion $)	4.3	1.2	0.05	-0.06
Return on sales %	14.4	10.1	0.7	-6.9
Equity capital (billion $)	0.39	0.12	0.23	0.04
Retained earnings (billion $)	27.1	10.8	0.59	-0.30
Long-term debt (billion $)	-15.2	-4.7	2.5	0.88

4.3 Optimistic and Pessimistic Case

The cases when the variables related to fuel economy measures assume optimistic and pessimistic values are now considered. In the optimistic case, it is assumed that the fuel economy gains achieved from the various technological improvements are higher than predicted by DOT, and that the costs, both manufacturing and capital investment, are less than those predicted by DOT. In the pessimistic case, the fuel economy gains are less and the costs are higher than those predicted by DOT. The actual values used, were decided upon in consultation with industry experts, and are given in Tables 4-3 and 4-4. All the data, besides that for the fuel economy related variables, are set at their nominal values.

Tables 4-5 to 4-8 compare the optimistic, nominal, and pessimistic case results for each of the manufacturers. It is noted that for each manufacturer, the fuel economy without mix shifts improves in the optimistic case (with respect to the nominal case), but not as much as it worsens in the pessimistic case.

TABLE 4-3. COSTS RELATED TO FUEL ECONOMY MEASURES
(Optimistic Data)

	Capital cost per car	Additional variable manufacturing cost
Downsizing	875	*
Material substitution	43.8	*
Automatic transmission	438.0	40.0
Manual transmission	21.88	22.2
Lubricants	0.0	4.73
Accessories	21.88	8.75
Aerodynamic drag	0.0	8.75
Rolling resistance	0.0	30.63

Source: Based on judgment of an industry expert.

TABLE 4-4 COSTS RELATED TO FUEL ECONOMY MEASURES

(Pessimistic Data)

	Capital cost per car	Additional variable manufacturing cost
Downsizing	1550	*
Material substitution	77.5	*
Automatic transmission	775.0	57.5
Manual transmission	38.8	27.8
Lubricants	0.0	5.28
Accessories	38.8	15.5
Aerodynamic drag	0.0	15.5
Rolling resistance	0.0	54.5

Source: Based on judgment of an industry expert.

*Effect on manufacturing costs depends on the weight reduction achieved.

TABLE 4-5. POSITION IN 1985, COMPANY G

	Optimistic case	Nominal case	Pessimistic case
Fuel economy without mix shifts (mpg)	25.75	25.2	23.8
Sales (million cars)	5.9	5.9	5.9
Breakeven (million cars)	2.7	2.7	2.8
Revenue (billion $)	29.7	29.9	30.5
After-tax profit (billion $)	4.2	4.3	4.2
Return on sales %	14.1	14.4	13.8
Equity capital (billion $)	0.39	0.39	0.39
Retained earnings (billion $)	27.4	27.1	24.8
Long-term debt (billion $)	-16.1	-15.2	-10.6

TABLE 4-6. POSITION IN 1985, COMPANY F

	Optimistic case	Nominal case	Pessimistic case
Fuel economy without mix shifts (mpg)	25.7	25.1	23.8
Sales (million cars)	2.7	2.7	2.7
Breakeven (million cars)	1.4	1.4	1.6
Revenue (billion $)	12.1	11.9	11.5
After-tax profit (billion $)	1.3	1.2	0.89
Return on sales %	10.7	10.1	7.7
Equity capital (billion $)	0.12	0.12	0.12
Retained earnings (billion %)	11.1	10.8	9.2
Long-term debt (billion $)	-5.4	-4.7	-1.9

TABLE 4-7. POSITION IN 1985, COMPANY C

	Optimistic case	Nominal case	Pessimistic case
Fuel economy without mix shifts (mpg)	26.0	25.4	24.1
Sales (million cars)	1.6	1.6	1.6
Breakeven (million cars)	1.6	1.5	1.4
Revenue (billion $)	7.1	7.2	7.5
After-tax profit (billion $)	0.01	0.05	0.15
Return on sales %	0.1	0.7	2.0
Equity capital (billion $)	0.23	0.23	0.23
Retained earnings (billion $)	0.65	0.59	0.27
Long-term debt (billion $)	2.3	2.5	3.4

TABLE 4-8. POSITION IN 1985, COMPANY A

	Optimistic case	Nominal case	Pessimistic case
Fuel economy without mix shifts (mpg)	24.6	24.2	23.2
Sales (million cars)	0.25	0.25	0.25
Breakeven (million cars)	0.33	0.35	0.43
Revenue (billion $)	0.88	0.87	0.84
After-tax profit (billion $)	-0.05	-0.06	-0.10
Return on sales %	-5.7	-6.9	-11.9
Equity capital (billion $)	0.04	0.04	0.04
Retained earnings (billion $)	-0.25	-0.30	-0.51
Long-term debt (billion $)	0.80	0.88	1.22

Considering the financial performance of the manufacturers, Company G's profit position is essentially unchanged in all the three cases. However, if the long-term debt in 1985, which can be thought of as an indicator of cumulative performance for the period 1977-85 is looked at, it can be seen that Company G is better off by 5.9 percent in the optimistic case compared to the nominal case. But in the pessimistic case, it is worse off by 30.2 percent compared to the nominal case. These results may be interpreted that the nominal case gives the best one-point predictions given the best one-point estimates of the relevant data. If the fuel economy related variables are realized with optimistic values (i.e., higher gains and lower costs), the financial performance would improve slightly compared to the nominal case. While, if the fuel economy related variables are realized with pessimistic values, the performance would be significantly worse than in the nominal case. In other words, the down side risk is high. Shortly, it is shown that these remarks about the down side risk apply to the other three manufacturers also.

In the case of Company F, the after-tax profit in 1985 exhibits the similar effect of high down side risk, though not in as pronounced a manner as that for long-term debt in 1985.

The profit position of Company C exhibits an apparently counter-intuitive result. Company C makes less profit in the optimistic case than in the pessimistic case. However, this is due to the fact that the fuel economy without mix shifts is higher for Company C than for the other three manufacturers. Thus, in the pessimistic case, the other three manufacturers are forced to resort to greater mix shifts (i.e., greater compared to that for the nominal case) than is the case for Company C, with the result that price differentials determined by the Price module favor Company C more in the pessimistic case than in the nominal case. Thus, the revenue for Company C is higher in the pessimistic case than in the optimistic case, which accounts for the behavior of the after-tax profit figures. However, the long-term debt figures exhibit the high down side risk behavior similar to the other manufacturers.

The results for Company A are as expected. The profit figures exhibit a high down side risk in as pronounced a manner as do the long-term debt figures.

4.4 Probabilistic Case

The probabilistic case comes from the premise that the values for the fuel economy related variables are not known with certainty; rather, probability distributions for each of these variables are known. The probability distribution assumed is a truncated normal distribution for all the probabilistic variables. The parameters of the distribution are based on the judgment of an industry expert, and are given in Tables 4-9 and 4-10. The probability distributions are given in Tables 4-11 to 4-13. The computer results for this case are given in Appendix A.

There is a remarkable correspondence between the results obtained in this case and the expectations based on the earlier analysis of the optimistic, nominal and pessimistic cases. It is worthwhile comparing the results for the long-term debt position. (See Table 4-14). The 0.1 fractile corresponds fairly well with the optimistic case, while the 0.9 fractile corresponds to the pessimistic case. Thus, the range of values of the long-term debt is roughly the same whether the estimate comes from the probabilistic case analysis or the pessimistic and optimistic case analyses. Also, as would be expected from the earlier remarks about high down side risk, the median values (i.e., 0.5 fractile values) are well above the nominal case values. That is, the probability that the long-term debt for any company is greater than or equal to the nominal case value is significantly greater than .5.

TABLE 4-9. FUEL ECONOMY GAINS FROM TECHNOLOGICAL IMPROVEMENTS

(Probabilistic case)

Option	Minimum value	Most likely value	Standard deviation	Maximum value
Automatic transmission	3.75%	10%	3 %	12.2 %
Manual transmission	3.75	5	0.63	6.25
Lubricants	0.0	2	0.6	2.5
Accessories	0.75	2	0.63	3.25
Aerodynamic drag	0.67	4	1.67	4.5
Rolling resistance	1.3	3	0.85	4.7

Source: Judgment of an industry expert.

TABLE 4-10. COSTS RELATED TO FUEL ECONOMY MEASURES

(Probabilistic case)

	Capital cost per car			
	Minimum value	Most likely value	Standard deviation	Maximum value
Downsizing	750	1000	550	2100
Material substitution	37.5	50.0	27.5	105.0
Automatic transmission	375	500	275	1050
Manual transmission	18.75	25.0	13.75	52.5
Lubricants	0.0	0.0	0.0	0.0
Accessories	18.75	25.0	13.75	52.5
Aerodynamic drag	0.0	0.0	0.0	0.0
Rolling resistance	0.0	0.0	0.0	0.0
	Additional variable manufacturing cost			
Automatic transmission	35.0	45.0	12.0	70.0
Manual transmission	19.4	25.0	2.8	30.6
Lubricants	4.45	5.0	0.3	5.55
Accessories	7.5	10.0	5.5	21.0
Aerodynamic drag	7.5	10.0	5.5	21.0
Rolling resistance	26.25	35.0	19.4	74.0

Source: Based on judgment of an industry expert.

TABLE 4-11. FUEL ECONOMY GAINS FROM TECHNOLOGICAL IMPROVEMENTS PROBABILITY DISTRIBUTION

	Fractiles				
Option	0.1	0.25	0.5	0.75	0.9
Automatic transmission	6.16%	7.57%	9.31%	10.6%	11.59%
Manual transmission	4.29	4.62	5.0	5.4	5.77
Lubricants	1.15	1.50	1.85	2.15	2.35
Accessories	1.29	1.62	2.0	2.4	2.77
Aerodynamic drag	1.76	2.46	3.27	3.92	4.30
Rolling resistance	2.04	2.48	3.0	3.54	4.05

Source: Computed from Table 4-9.

TABLE 4-12

CAPITAL COSTS RELATED TO FUEL ECONOMY MEASURES PROBABILITY DISTRIBUTION

	Capital cost per car				
	Fractiles				
Option	0.1	0.25	0.5	0.75	0.9
Downsizing	852	989	1220	1501	1753
Material substitution	43	49	61	75	88
Automatic transmission	426	489	610	750	877
Manual transmission	21	24	31	38	44
Lubricants	0	0	0	0	0
Accessories	21	24	31	38	44
Aerodynamic drag	0	0	0	0	0
Rolling resistance	0	0	0	0	0

Source: Computed from Table 4-10.

TABLE 4-13. ADDITIONAL VARIABLE MANUFACTURING COSTS RELATED TO FUEL ECONOMY MEASURES PROBABILITY DISTRIBUTION

Option	Cost per car				
	Fractiles				
	0.1	0.25	0.5	0.75	0.9
Automatic transmission	37.9	41.8	47.8	54.5	60.9
Manual transmission	22	23	25	27	28
Lubricants	4.7	4.8	5.0	5.2	5.3
Accessories	8.5	9.9	12.2	15.0	17.5
Aerodynamic drag	8.5	9.9	12.2	15.0	17.5
Rolling resistance	29.8	34.6	42.8	52.7	61.6

Source: Computed from Table 4-10.

TABLE 4-14. LONG-TERM DEBT IN 1985 (billion $)

	Probabilistic case					Optimistic case	Nominal case	Pessimistic case
	Fractiles							
	0.1	0.25	0.5	0.75	0.9			
Company G	-15.7	-14.0	-12.7	-11.1	-9.7	-16.1	-15.2	-10.6
Company F	- 4.7	- 4.0	- 3.5	- 2.7	-1.9	- 5.4	- 4.7	- 1.9
Company C	2.4	2.8	3.1	3.4	3.8	2.3	2.5	3.4
Company A	0.87	0.95	1.04	1.11	1.23	0.80	0.88	1.22

4.5 Technological and Manufacturing Risk

The risk due to the uncertainty in the fuel economy gains achieved from the various fuel economy measures can be thought of as a technological risk. Manufacturing risk can be thought of as being due to the uncertainty in the costs, both variable cost of production and capital costs, of implementing these measures. In the analysis above, the fuel economy gains and the costs of the measures have been varied simultaneously. Thus, the joint impact of the uncertainties in the technological and manufacturability areas have been assessed. In this section, an attempt is made to separate the two impacts.

It must be assumed that the costs related to the fuel economy measures are realized at their nominal values, while, first, the fuel economy gains are realized at the optimistic values, and then at the pessimistic values. Next, it is assumed that the fuel economy gains are realized at their nominal values, while the related costs are at the optimistic, and then pessimistic values. Thus, there are four cases. The results of these four cases, along with the results of the first three cases analyzed earlier, are presented in Table 4-15. Only the long-term debt position in 1985 in these comparisons is considered, since that is probably the best overall measure of performance.

From Table 4-15 it is seen that for each manufacturer, the variation in a column is much less than the variation in a row. The variation in a column is the variation in performance as fuel economy gains vary, assuming that the related costs remain constant. In that sense, the variation in a column can be considered to be an indicator of risk due to technological uncertainty. Similarly, variation in a row can be considered to be an indicator of risk due to uncertainty in the area of manufacturability. It is thus concluded that the risk due to uncertainty in manufacturing appears to be higher than the risk due to technological uncertainty.

Fuel economy gains being held constant, each manufacturer performs better as costs change from pessimistic to optimistic, as is to be expected. Costs being held constant, as fuel economy gains change from pessimistic to optimistic, Company F and Company A perform better while Company G and Company C perform worse. It is not easy to see the cause of this behavior intuitively, since pessimistic fuel economy gains cause larger

TABLE 4-15. DEBT POSITION IN 1985 (BILLION $)
COSTS RELATED TO FUEL ECONOMY MEASURES

FUEL ECONOMY GAINS	OPTIMSTIC	NOMINAL	PESSIMISTIC
OPTIMISTIC	−16.1	−14.9	--
NOMINAL	−16.4	−15.2	−9.8
PESSIMISTIC	--	−16.3	−10.6

COMPANY G

FUEL ECONOMY GAINS	OPTIMISTIC	NOMINAL	PESSIMISTIC
OPTIMISTIC	−5.4	−4.8	--
NOMINAL	−5.4	−4.7	−2.2
PESSIMISTIC	--	−4.5	−1.9

COMPANY F

FUEL ECONOMY GAINS	OPTIMISTIC	NOMINAL	PESSIMISTIC
OPTIMISTIC	2.3	2.6	--
NOMINAL	2.2	2.5	3.8
PESSIMISTIC	--	2.0	3.4

COMPANY C

FUEL ECONOMY GAINS	OPTIMISTIC	NOMINAL	PESSIMISTIC
OPTIMISTIC	0.80	0.86	--
NOMINAL	0.81	0.88	1.15
PESSIMISTIC	--	0.93	1.22

COMPANY A

mix shifts which, given the current mix and fuel economy by size-class for each manufacturer, favor Company G and Company C. Such behavior is one of the insights yielded by the model. This result should not be interpreted in an absolute sense; rather, the correct interpretation is that if fuel economy gains are realized at the pessimistic values, Company F and Company A are hurt more than Company G and Company C.

5. ANALYSIS OF DIFFERENT SCENARIOS

5.1 General

In the previous section several situations were analyzed under the nominal scenario. The values of the variables describing the scenario were fixed, and the values of the fuel economy related variables were varied. In this section, different scenarios are examined, while, for the most part, the values of the fuel economy related variables are assumed to be the nominal values. In the first scenario, it is assumed that the capital expenditures by the manufacturers are higher than estimated by the nominal data. In the second scenario, a hypothetical situation is analyzed in which the AFES do not exist. In the third scenario, it is assumed that the AFES are higher than is actually the case. The next two scenarios are aimed at analyzing market risk: in one the effect of the foreign manufacturers entering the mid-size car market is examined, while the other examines one case of a shift in market shares of the domestic manufacturers. Finally, three scenarios are formulated to examine economic risk. In these scenarios, the projections of total automobile demand are changed.

5.2 Increased Capital Expenditure

A recent report [22] produced by DOT, and conversations with personnel from the Transportation Systems Center of DOT, showed that the data input for the Nominal case discussed earlier might significantly underestimate the capital expenditure of the manufacturers. Table 5-1 compares the capital expenditures estimates for the period 1978-85 based on the above report [22] with the output of the model for the Nominal case. The revised estimates and the Nominal case results agree to within 5 percent for Company A; however, for Companies G, F and C the difference is very large. For these three companies, the revised estimates of capital expenditure are greater than the Nominal case results by 50 to 100 percent.

The objective of the "Increased Capital Expenditure" scenario is to analyze the impact of AFES on the manufacturers if it is assumed that their capital expenditures are as high as the revised estimates given in Table 5-1. In this scenario, all the input data for

the model are the same as in the Nominal case except that the data relating to capital expenditure are adjusted so that the total capital expenditure for the period 1978-85 for each manufacturer is equal to the revised estimates given in Table 5-1. Figure 5-1 gives the after-tax profit, net cash inflow and the capital investment for each manufacturer for the period 1977-85 for the "Increased Capital Expenditure" scenario. Table 5-2 gives the financial position in 1985 for each manufacturer under this scenario.

TABLE 5-1. CUMULATIVE CAPITAL EXPENDITURES FOR 1978-85
(billion $)

	Company G	Company F	Company C	Company A
Revised estimates*	23.4	12.9	5.04	0.72
Nominal case	15.8	6.56	3.29	0.68

*These figures are for North American passenger operations only and are based on "The Impact of Federal Regulation on the Financial Structure and Performance of the Domestic Motor Vehicle Manufacturers," U.S. Department of Transportation, May 1978.

TABLE 5-2. INCREASED CAPITAL EXPENDITURE SCENARIO
FINANCIAL POSITION 1985

	Company G	Company F	Company C	Company A
Sales (million cars)	5.94	2.71	1.62	0.25
Breakeven (million cars)	3.00	1.97	1.87	0.36
Revenue (billion $)	29.9	11.9	7.2	0.87
After-tax profit (billion $)	3.57	0.62	-0.14	-0.07
Return on sales (%)	11.9	5.2	-1.9	-8.0
Equity capital (billion $)	0.39	0.12	0.23	0.04
Retained earnings (billion $)	22.75	7.26	-0.52	-0.33
Long-term debt (billion $)	-7.41	2.07	4.5	0.93

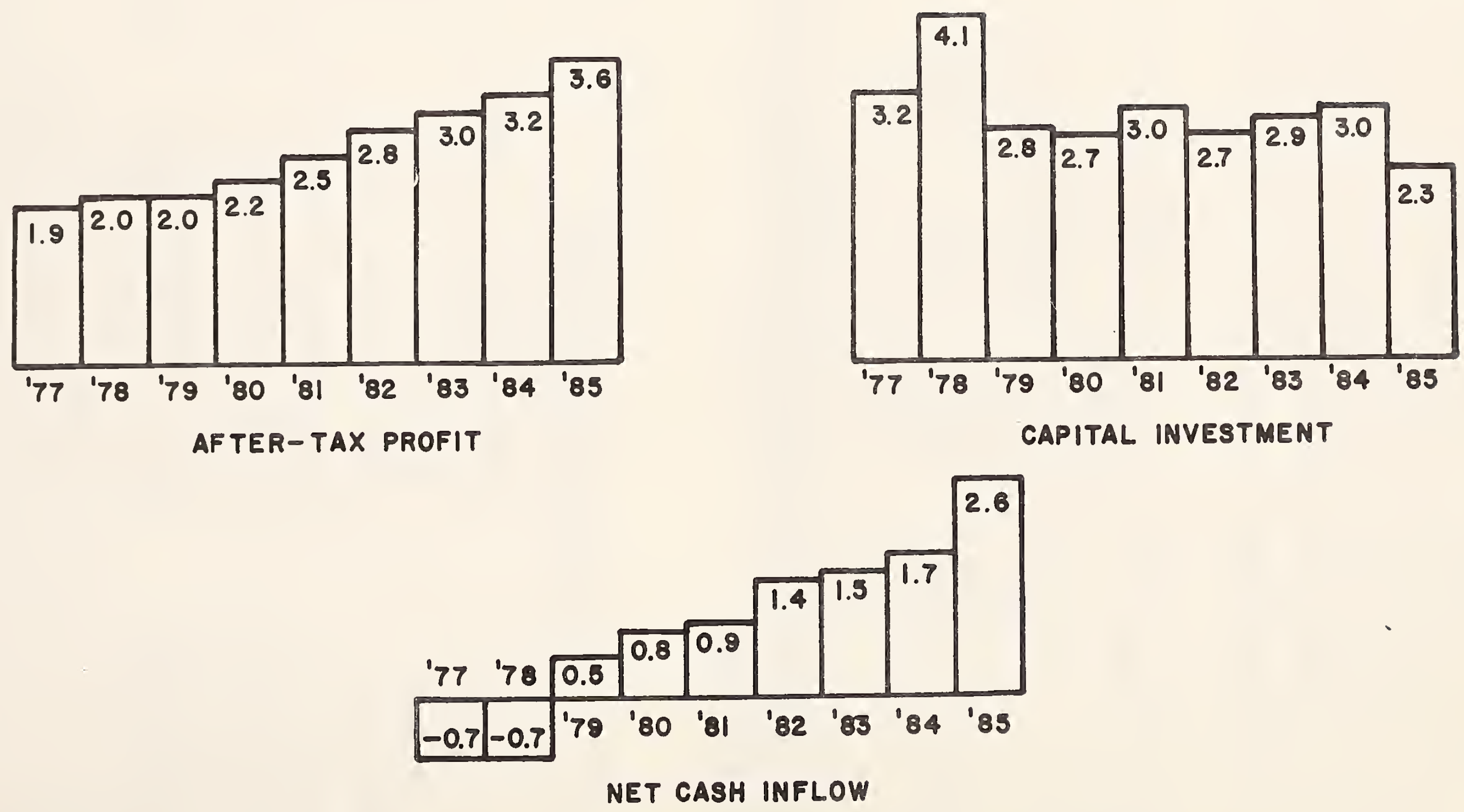

FIGURE 5-1. INCREASED CAPITAL EXPENDITURE SCENARIO, COMPANY G (BILLION $)
(SHEET 1 OF 4)

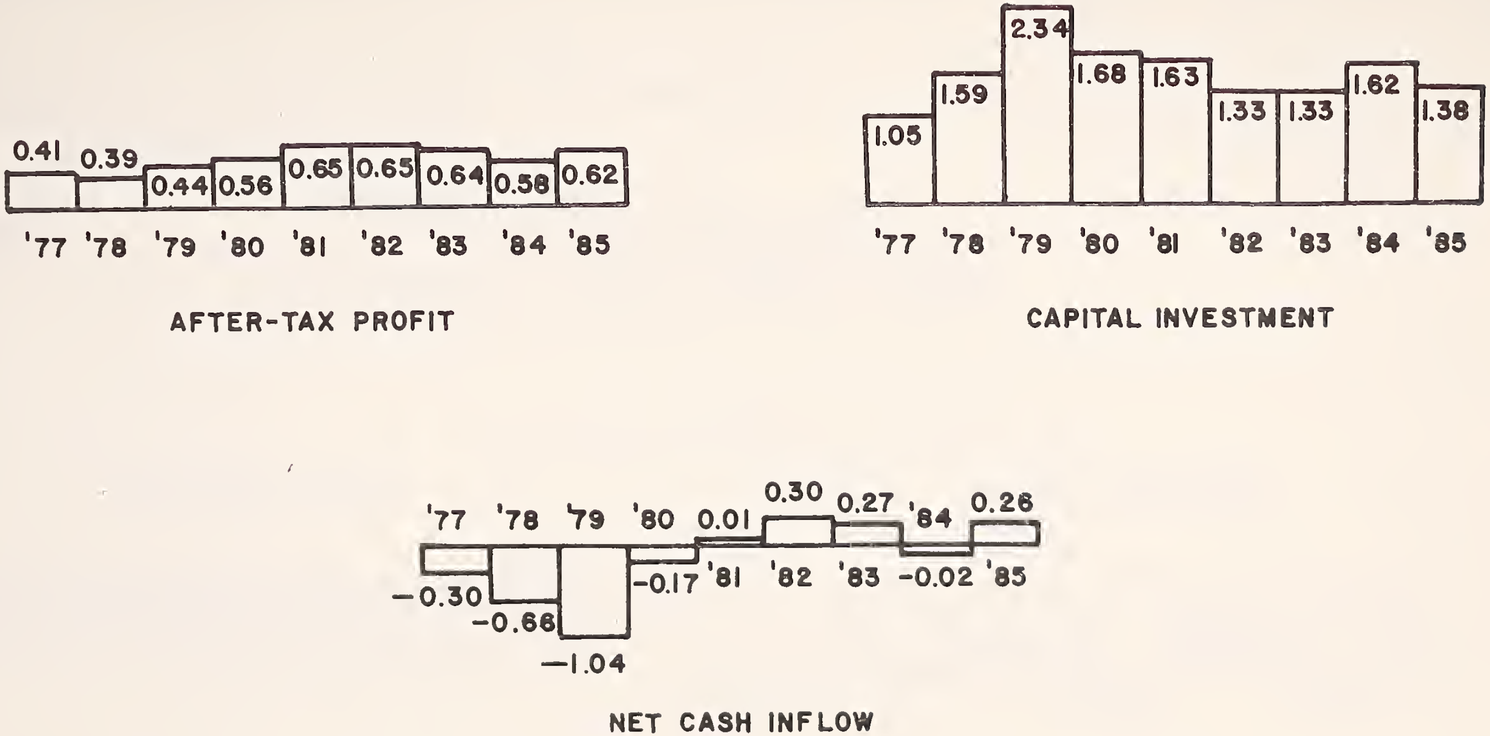

FIGURE 5–1. INCREASED CAPITAL EXPENDITURE SCENARIO, COMPANY F (BILLION $)

(SHEET 2 OF 4)

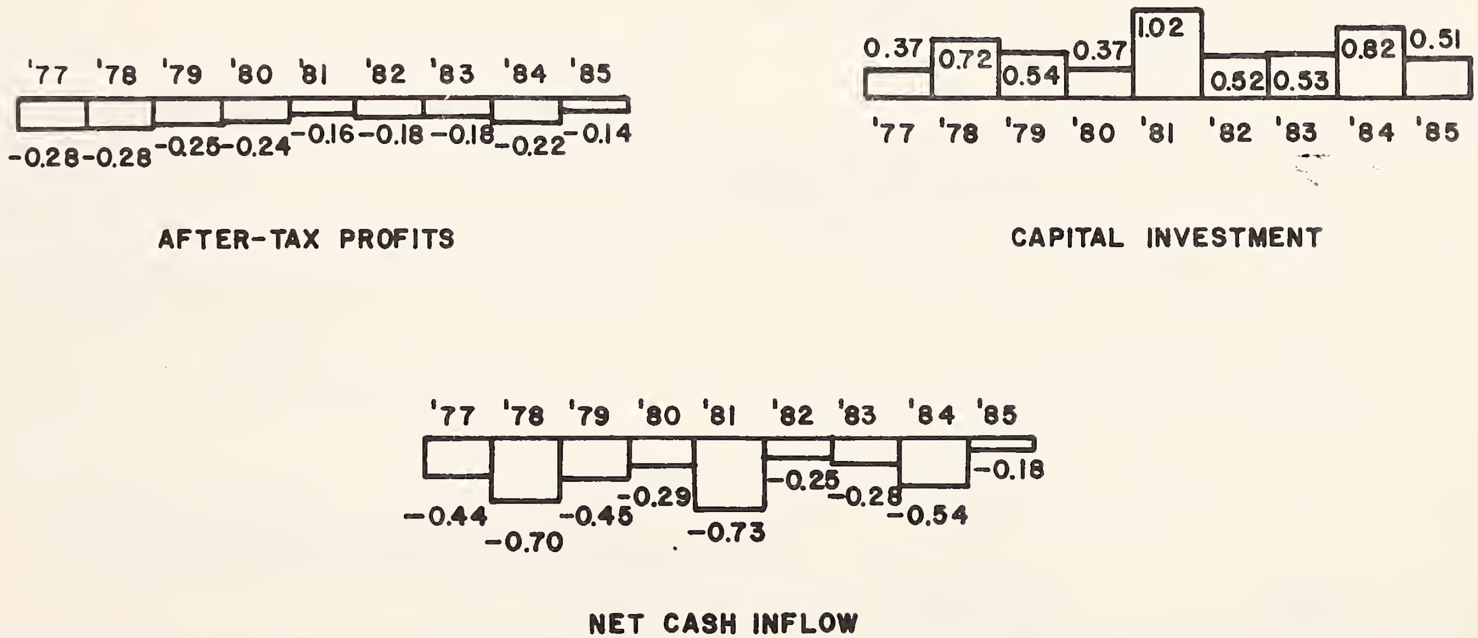

FIGURE 5-1. INCREASED CAPITAL EXPENDITURE SCENARIO, COMPANY C (BILLION $)
(SHEET 3 OF 4)

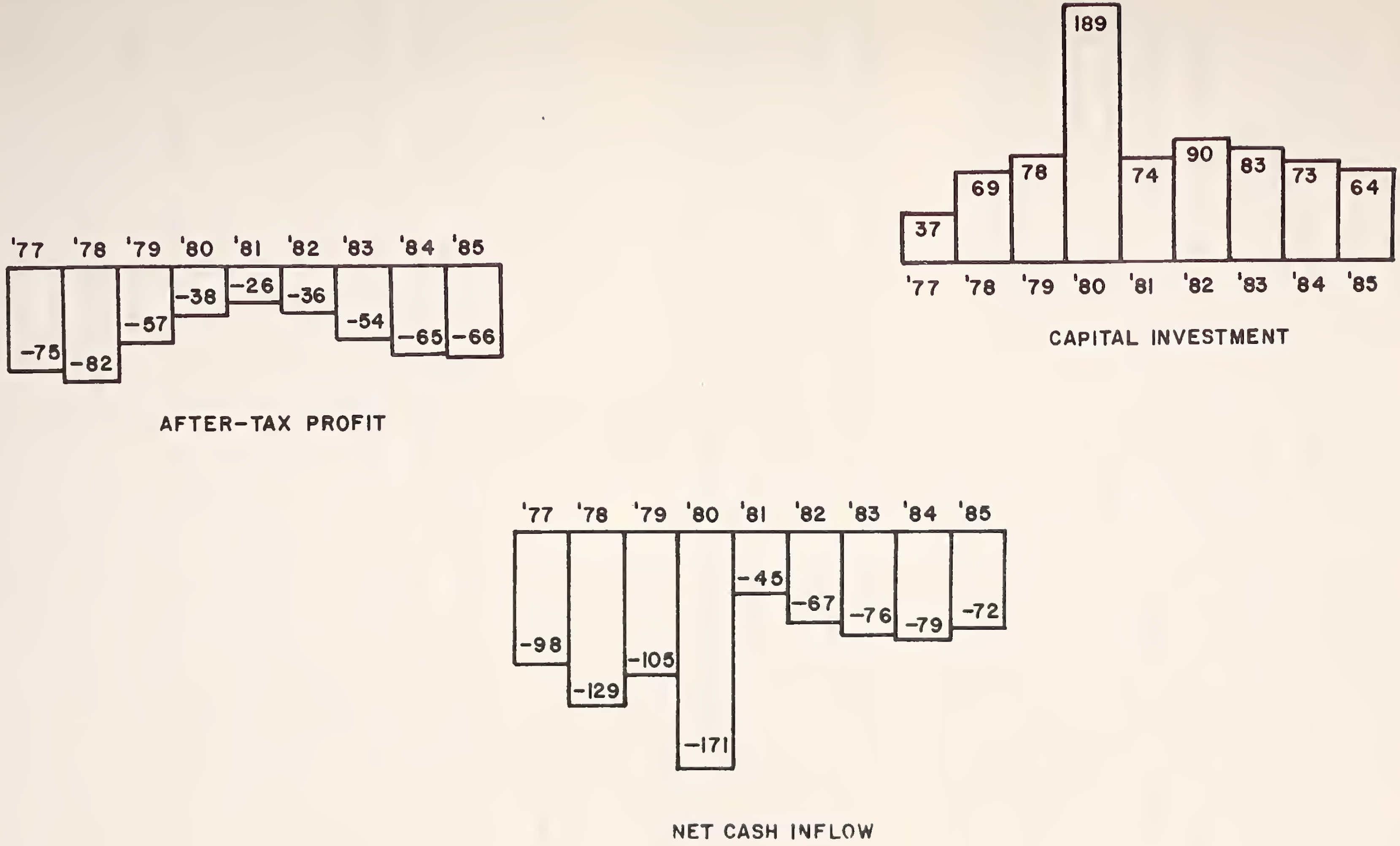

FIGURE 5-1. INCREASED CAPITAL EXPENDITURE SCENARIO, COMPANY A (BILLION $)
(SHEET 4 OF 4)

When the results of this scenario are compared with the Nominal case, it is seen that Companies G, F and C are significantly worse off under this scenario, while Company A is only marginally worse off. This is to be expected since the capital expenditure for Company A was increased by only about 5 percent, whereas for Companies G, F and C, the increases were 48, 97 and 53 percent respectively. The revenue for each manufacturer is the same under the two scenarios, since only the data relating to capital expenditure were adjusted upward in the "Increased Capital Expenditure Scenario." Thus, for the same revenue, Company G's after-tax profits decreased by 17 percent, Company F's by 48 percent, Company C's by 380 percent and Company A's by 10 percent under this scenario. Another finding worth noting is, that while under the Nominal case Company C exhibited a trend towards profitability over the period 1977-85, it exhibits no such trend under this scenario.

Considering the capital structure in 1985 under this scenario, it is seen that Company G is in a strong position. It has liquidated all its debt and has built up a credit balance of $7.4 billion. Company F is also in a strong position; its debt/equity ratio is a healthy 0.28. Companies C and A are both in clearly untenable positions. Both have negative retained earnings. Both the companies would have had to take some drastic actions to avoid reaching such a position.

5.3 "Ideal" Scenario

In this section a scenario is analyzed which is ideal from the perspective of the manufacturers. In this scenario, the AFES is not enforced; thus the manufacturers <u>do not have to</u>, but may, implement the various fuel economy measures. It is assumed that a manufacturer will implement a particular fuel economy measure only if it is economically profitable for him to do so. Then, under the assumptions made in the model, the manufacturers will <u>not</u> implement the technological improvements in transmission, accessories, lubricants, aerodynamic drag, and rolling resistance because all these options involve increased capital and manufacturing costs with no compensating increase in revenue. The manufacturers will not, of course, under the assumptions of this model, change their product mix, since they do not have to meet any fuel economy standards. Regarding downsizing and material substitution, however, the situation is not so clear cut. Both these alternatives involve increased capital costs but, at the same time, decrease variable manufacturing costs.

The objective of analyzing this scenario is to determine how much better off the manufacturers are under this ideal scenario compared to the Nominal case. The analysis also determines whether it is economically profitable for the manufacturers to implement downsizing and material substitution. Two cases are considered under this scenario. In the first alternative, it is assumed that the manufacturers implement both downsizing and material substitution. In the second alternative, it is assumed that the manufacturers implement downsizing but do not implement material substitution. Tables 5-3 and 5-4 compare the results of these two cases with the Nominal case from the previous section.

TABLE 5-3 MARKET CHARACTERISTICS IN 1985

	Full-size	Mid-size	Compact	Sub-compact
Mix in Nominal case	0.11	0.23	0.25	0.40
Mix in "Ideal" scenario	0.20	0.28	0.23	0.29
Price in Nominal case ($)	9569	7184	4947	3689
Price in "Ideal" scenario	8225	5567	4990	3900

TABLE 5-4. FINANCIAL POSITION IN 1985
(billion $)

		Company G	Company F	Company C	Company A
After-tax profit	Nominal	4.3	1.2	0.05	-0.06
	Ideal scenario*	3.9	1.5	0.06	-0.01
	Ideal scenario**	3.8	1.5	0.06	-0.02
Long-term debt	Nominal	-15.2	-4.7	2.5	0.88
	Ideal scenario*	-16.6	-6.5	1.8	0.64
	Ideal scenario**	-16.3	-6.6	1.8	-0.64

*Alternative 1, i.e., both downsizing and material substitution are implemented.
**Alternative 2, i.e., only downsizing is implemented.

When the "Ideal Scenario, Alternative 1" is compared with the Nominal case, it can be seen that Companies F, C and A are in a better profit position in 1985 while Company G is worse off. This result should be interpreted in a relative sense, that is: not imposing AFES benefits Companies F, C and A more than it benefits Company G. As far as the 1985 debt position is considered, all of the four manufacturers are better off without AFES, as is to be expected. The debt position for Companies G, F, C and A is better by 9.2, 47, 28 and 27 percent respectively.

It is interesting to compare the "Ideal Scenario, Alternative 1" case with "Ideal Scenario, Alternative 2" case. Between these two cases, there is virtually no difference in the profit position or debt position for any of the manufacturers. The only difference between these two cases is that the first alternative implements material substitution while the second does not. From this, one can conclude that, under the assumptions of the model, downsizing is economically profitable while material substitution has no significant economic impact on the manufacturers. That is, for material substitution, the capital cost is almost exactly offset by the decrease in material cost.

5.4 Higher AFES

In this scenario, everything is the same as in the Nominal case except that the schedule of AFES is different. Here it is assumed that the AFES is the same as in the Nominal case for the years 1977-83; in 1984 it is 28.5 mpg instead of 27.0 in the Nominal case), and in 1985 it is 30.0 mpg (instead of 27.5 in the Nominal case). Results of the higher AFES case are compared with the Nominal case in Tables 5-5 and 5-6.

TABLE 5-5 MARKET CHARACTERISTICS IN 1985

	Full-size	Mid-size	Compact	Sub-compact
Mix in Nominal case	0.11	0.23	0.25	0.40
Mix in "Higher AFES" case	0.07	0.19	0.26	0.48
Price in Nominal case	9569	7184	4947	3689
Price in "Higher AFES" case	10782	8719	5085	3665

TABLE 5-6. FINANCIAL POSITION IN 1985
(billion $)

		Company G	Company F	Company C	Company A
After-tax profit	Nominal	4.3	1.2	0.05	-0.06
	Higher AFES	4.8	1.2	0.16	-0.09
Long-term debt	Nominal	-15.2	-4.7	2.5	0.88
	Higher AFES	-14.3	-4.6	2.8	0.92

TABLE 5-7. HIGHER AFES SCENARIO

POSITION AT END OF YEAR 1985

	FRACTILES 0.10	0.25	0.50	0.75	0.90
Company G					
DEBT	[illegible]	-13899.	-11424.	-10363.	-8332.
NET INCOME	22345.	24124.	25557.	26662.	27389.
AFT-TAX PROFIT	3213.	4428.	4692.	4889.	5151.
FUEL ECONOMY WITHOUT TAX SHIFTS	[illegible]	24.21	24.70	24.93	25.32
Company F					
DEBT	[illegible]	[illegible]	-3015.	-2156.	-1209.
NET INCOME	[illegible]	9364.	10006.	10508.	10823.
AFT-TAX PROFIT	[illegible]	749.	972.	1059.	1098.
FUEL ECONOMY WITHOUT TAX SHIFTS	[illegible]	24.26	24.66	24.88	25.30
Company C					
DEBT	2352.	2876.	3259.	3701.	4155.
NET INCOME	-363.	-91.	340.	559.	802.
AFT-TAX PROFIT	21.	98.	180.	312.	582.
FUEL ECONOMY WITHOUT TAX SHIFTS	24.19	24.55	24.97	25.22	25.62
Company A					
DEBT	838.	972.	1112.	1216.	1354.
NET INCOME	-553.	-504.	-403.	-344.	-273.
AFT-TAX PROFIT	-171.	-151.	-116.	-102.	-90.
FUEL ECONOMY WITHOUT TAX SHIFTS	23.30	23.56	23.82	24.01	24.18

Imposing higher AFES decreases the proportion of larger cars produced making the larger cars more expensive (see Table 5-5). The profit position in 1985 (see Table 5-6) shows that Companies C and G are better off with higher AFES, while Company A is worse off. Once again, it is emphasized that this result should be interpreted in a relative sense. From the 1985 debt position, it can be seen that all the manufacturers are worse off with the higher AFES, which corresponds with one's intuition. The debt positions for Companies G, F C and A are worse by 6, 2, 12 and 5 percent respectively under the "Higher AFES" scenario.

Under this scenario, it is next assumed that the fuel economy related variables are known only by their probability distribution. If it is assumed that the distributions are truncated normal and the parameters are as given in Section 4, then there is a case which is comparable to the probabilistic case discussed under the Nominal scenarios. The results of the probabilistic case discussed under the Nominal scenarios. The results of the probabilistic case under the higher AFES scenario are given in Table 5-7. When the results for these two cases are compared, the same conclusions as just stated above follow.

5.5 Foreign Penetration of Mid-size Car Market

In this scenario the product mix of the foreign manufacturers is changed as follows:

	Large	Mid-size	Compact	Subcompact
Nominal scenario	0.0	0.0	0.2	0.8
Scenario under consideration	0.0	0.1	0.3	0.6

Under this scenario two cases are discussed: First, the nominal values for the fuel economy related variables; second, the probability distribution for the fuel economy related variables.

Table 5-8 compares the nominal cases under the Nominal scenario with that under the "Foreign Penetration of Mid-size Car Market" scenario. Companies G, F, and C perform worse in "Foreign Penetration" scenario, with Company G being the most affected. Company A is relatively unaffected by the foreign penetration into the mid-size car market. This is understandable since in the "Foreign Penetration" scenario, the competitive pressure in the smaller car market is reduced; and since Company A is mostly in the smaller car market, Company A is thus not hurt by this move by foreign manufacturers.

TABLE 5.8 FINANCIAL POSITION IN 1985

(billion $)

		Company G	Company F	Company C	Company A
After-Tax profit	Nominal	4.3	1.2	0.05	0.06
	Foreign penetration	3.9	1.1	0.01	0.06
Long-term debt	Nominal	15.2	4.7	2.5	0.88
	Foreign penetration	12.7	4.4	2.9	0.90

Table 5-9 gives the results of the probabilistic case under the "Foreign Penetration" scenario. When this is compared with the Nominal case under the Nominal scenario, the same conclusions just stated above are arrived at.

The impact on financial performance considered in this scenario can be viewed as one form of marketing risk, since the penetration of the mid-size market by foreign manufacturers changes the competitive pressures in the market.

TABLE 5-9. FOREIGN PENETRATION OF MID-SIZE CAR MARKET SCENARIO

POSITION AT END OF YEAR 1985

	FRACTILES 0.10	0.25	0.50	0.75	0.90
Company G					
DEBT	-13657.	-12495.	-11257.	-8978.	-7886.
RET INCOME	21470.	22134.	23721.	24636.	25134.
AFT-TAX PROFIT	3516.	3651.	3791.	3969.	4090.
FUEL ECONOMY WITHOUT MIX SHIFTS	24.12	24.44	24.69	25.13	25.36
Company F					
DEBT	-4571.	-4191.	-3529.	-2520.	-1798.
RET INCOME	8845.	9227.	9941.	10247.	10511.
AFT-TAX PROFIT	916.	945.	1020.	1096.	1137.
FUEL ECONOMY WITHOUT MIX SHIFTS	24.11	24.43	24.66	25.08	25.32
Company C					
DEBT	2645.	2926.	3221.	3750.	4036.
RET INCOME	-508.	-324.	10.	251.	380.
AFT-TAX PROFIT	-140.	-89.	-30.	11.	98.
FUEL ECONOMY WITHOUT MIX SHIFTS	24.45	24.78	24.99	25.42	25.63
Company A					
DEBT	871.	909.	1013.	1128.	1235.
RET INCOME	-537.	-480.	-394.	-339.	-314.
AFT-TAX PROFIT	-95.	-88.	-75.	-64.	-61.
FUEL ECONOMY WITHOUT MIX SHIFTS	23.52	23.65	23.86	24.13	24.22

5.6 Change in Market Shares

Another way to examine market risk is to change the market shares of the domestic manufacturers. Here one scenario is examined in which Company C's share is decreased by 1.5 percentage points, Company G's share is increased by 1 percentage point and Company F's share is increased by 0.5 percentage point. As expected, Companies G and F perform better, and Company C performs worse, as is shown in Table 5-10.

TABLE 5-10. POSITION IN 1985

		Company G	Company F	Company C	Company A
After-tax profit	Nominal	4.3	1.2	0.05	-0.06
	Changing share	4.34	1.25	-0.014	-0.059
Long-term debt	Nominal	-15.2	-4.7	2.5	0.88
	Changing share	-15.6	-4.96	2.77	0.87

5.7 Economic Risk

Using this model, economic risk can be assessed by changing the values of the total automobile demand over the period of analysis. In the Nominal case the WEFA model's projection of U.S. automobile demand is used.

Here, three scenarios obtained by changing the demand projection are analyzed. In the first scenario, it is assumed that the demand in each year is 5 percent more than that predicted by the WEFA model. In the second scenario, the demand in each year is 5 percent less than that predicted by the WEFA model. Finally, in the third scenario, it is assumed that the demand is more cyclical than predicted by the WEFA model. Specifically, the following demand projection is assumed in the third scenario:

Year	Total Demand (million cars)
1977	11.3
1978	10.6
1979	11.5
1980	12.7
1981	12.7
1982	11.5
1983	12.2
1984	13.3
1985	12.4

This demand projection is obtained by taking the demand projection from the WEFA model as a base and superimposing on that a cyclical pattern similar to the one observed during the last ten years. More specifically, the cyclical pattern superimposed is such that the difference between the peak and trough of a cycle is 2 million cars. It should be noted that the average demand per year under this scenario is the same as that under the Nominal scenario. In all the three scenarios, all data besides the total demand is the same as in the Nominal case under the Nominal scenario.

In order to better capture the effect of cyclicality, a small change was made in the model when the cyclical demand scenario was analyzed. In this model, some of the costs are semi-variable; these costs are: Selling and General Administration, Research and Development, and Maintenance, Repair and Rearrangement. In reality, such costs tend to be semi-variable upwards but fixed downwards. That is, when revenues go up, these costs also go up (though not proportionally), but when revenues go down, these costs tend to remain fixed. This behavior is particularly significant in a cyclical demand situation. Therefore, this feature was incorporated in the model only for the cyclical scenario. To that extent, the results of the cyclical scenario are not strictly comparable to the results of the other scenarios. However, because the demand in the other scenarios has very little cyclicality, this feature would not significantly affect their results. Therefore, the results of the four scenarios are fairly comparable.

TABLE 5-11. COMPANY G POSITION IN 1985

	Nominal	High Demand	Low Demand	Cyclical Demand
Sale	5.9	6.2	5.7	5.9
Breakeven	2.7	2.7	2.6	2.7
After-tax profit	4.3	4.6	3.9	4.3
Long-term debt	-15.2	-17.4	-13.0	-15.0
Retained income	27.1	29.4	24.7	26.9

TABLE 5-12. COMPANY F POSITION IN 1985

	Nominal	High Demand	Low Demand	Cyclical Demand
Sale	2.7	2.84	2.58	2.71
Breakeven	1.4	1.45	1.39	1.42
After-tax profit	1.2	1.32	1.11	1.21
Long-term debt	-4.7	-5.47	-4.08	-4.67
Retained income	10.8	11.5	9.97	10.7

TABLE 5-13. COMPANY C POSITION IN 1985

	Nominal	High Demand	Low Demand	Cyclical Demand
Sale	1.6	1.70	1.54	1.6
Breakeven	1.5	1.55	1.50	1.6
After-tax profit	0.05	0.08	0.02	0.04
Long-term debt	2.5	2.38	2.62	2.63
Retained income	0.59	0.76	0.42	0.53

TABLE 5-14. COMPANY A POSITION IN 1985

	Nominal	High Demand	Low Demand	Cyclical Demand
Sale	0.25	0.26	0.24	0.25
Breakeven	0.35	0.35	0.35	0.37
After-tax profit	-0.06	-0.06	-0.07	-0.07
Long-term debt	0.88	0.85	0.90	0.93
Retained income	-0.30	-0.26	-0.34	-0.34

Tables 5-11 to 5-14 present the results of the three scenarios analyzed here and of the Nominal case. As is to be expected, all manufacturers perform better under high demand scenarios and worse under the low demand and cyclical demand scenarios. The results yield another, and more interesting conclusion. Table 5-15 gives the change in long-term debt position in 1985 under the various demand projections compared to the Nominal case. It can be seen that Companies G and F are not affected very much by the cyclicality in demand. For Companies G and F, the effect of a persistently low demand is much more significant than that of cyclicality; the effect of low demand is of the order of 13 to 14 percent, while that of cyclical demand is only about 1 percent. For Company C, the effects of low demand and cyclical demand are equally significant; both worsen the debt position by 5 percent. While for Company A, the effect of cyclical demand (6 percent) is more significant than that of low demand (2 percent).

TABLE 5.15 CHANGE IN LONG-TERM DEBT POSITION IN 1985, COMPARED TO THE NOMINAL CASE

	High Demand	Low Demand	Cyclical Demand
Company G	-14%	14%	1%
Company F	-16%	13%	1%
Company C	-5%	5%	5%
Company A	-3%	2%	6%

APPENDIX A

Results under the Nominal Scenario

The computer printed results of two cases under the Nominal scenario are presented: the Nominal case, and the Probabilistic case. In the Nominal case, the full financial statements have been printed out only for 1977 and 1985, while a summary of the financial statements has been printed for each year.

Probabilistic Case

POSITION AT END OF YEAR 1985

	FRACTILES 0.10	0.25	0.50	0.75	0.90
Company G					
DEBT	-15704.	-13973.	-12676.	-11121.	-9700.
RET INCOME	23680.	24302.	25723.	26319.	27535.
AFT-TAX PROFIT	3852.	3972.	4168.	4277.	4396.
FUEL ECONOMY WITHOUT MIX SHIFTS	24.11	24.32	24.67	25.12	25.34
Company F					
DEBT	-4688.	-4031.	-3502.	-2698.	-1948.
RET INCOME	9063.	9451.	10028.	10299.	10704.
AFT-TAX PROFIT	957.	1018.	1079.	1124.	1184.
FUEL ECONOMY WITHOUT MIX SHIFTS	24.10	24.31	24.64	25.07	25.29
Company C					
DEBT	2356.	2769.	3125.	3364.	3782.
RET INCOME	-136.	25.	312.	508.	727.
AFT-TAX PROFIT	-86.	-39.	40.	107.	149.
FUEL ECONOMY WITHOUT MIX SHIFTS	24.41	24.63	24.97	25.36	25.61
Company A					
DEBT	874.	948.	1042.	1106.	1225.
RET INCOME	-536.	-471.	-406.	-347.	-309.
AFT-TAX PROFIT	-100.	-90.	-81.	-73.	-64.
FUEL ECONOMY WITHOUT MIX SHIFTS	23.45	23.59	23.84	24.04	24.21

Nominal Case

Company G

INCOME STATEMENT FOR YEAR 1977

SALES REVNUE		25368.2
VARIABLE COSTS		15896.3
FIXED COSTS		
SEL & ADM	779.1	
RES &DEV	761.8	
MAIN, REP, & REA.	1431.5	
RETIREMENT	497.0	
NON-INCOME TAX	645.0	
DEPRECIATION	317.3	
AMORTISATION	845.6	
INTEREST	221.8	
		5499.2
PRE-TAX INCOME		3972.6
INCOME TAX		1863.2
AFTER-TAX INCOME		2109.5

CASH FLOW STATEMENT FOR YEAR 1977

SOURCES		USES	
NET INCOME	2109.5	CAP INV	2292.7
DEPRECIATION	317.3	DIVIDEND	821.1
AMORTISATION	845.6	DEBT RED	158.6
TOTAL	3272.4	TOTAL	3272.4

BALANCE SHEET FOR YEAR 1977

LAND &BLDG	1789.2	EQUITY	393.8
M/C &EQPT	2671.3	DEBT	392.6
TOOLING	845.6	RETAINED INCOME	8315.4
OTHER ASSETS	3796.0		
TOTAL	9101.8	TOTAL	9101.8

Company F

INCOME STATEMENT FOR YEAR 1977

SALES REVNUE		10689.5
VARIABLE COSTS		7801.8
FIXED COSTS		
SEL & ADM	466.1	
RES &DEV	316.1	
MAIN. REP. & REA.	338.4	
RETIREMENT	155.3	
NON-INCOME TAX	247.7	
DEPRECIATION	109.0	
AMORTISATION	195.5	
INTEREST	76.6	
		1904.6
PRE-TAX INCOME		983.0
INCOME TAX		448.3
AFTER-TAX INCOME		534.8

CASH FLOW STATEMENT FOR YEAR 1977

SOURCES		USES	
NET INCOME	534.8	CAP INV	254.7
DEPRECIATION	109.0	DIVIDEND	135.8
AMORTISATION	195.5	DEBT RED	448.8
TOTAL	839.3	TOTAL	839.3

BALANCE SHEET FOR YEAR 1977

LAND &BLDG	873.3	EQUITY	121.8
M/C &EQPT	1149.2	DEBT	278.1
TOOLING	391.7	RETAINED INCOME	3937.8
OTHER ASSETS	1923.6		
TOTAL	4337.7	TOTAL	4337.7

Company C

INCOME STATEMENT FOR YEAR 1977

SALES REVNUE		6115.9
VARIABLE COSTS		5490.3
FIXED COSTS		
SEL & ADM	223.3	
RES &DEV	135.4	
MAIN. REP. & REA.	215.9	
RETIREMENT	110.3	
NON-INCOME TAX	111.8	
DEPRECIATION	43.2	
AMORTISATION	127.9	
INTEREST	62.2	
		1029.8
PRE-TAX INCOME		-404.2
INCOME TAX		-158.9
AFTER-TAX INCOME		-245.4

CASH FLOW STATEMENT FOR YEAR 1977

SOURCES		USES	
DEPRECIATION	43.2	NET LOSS	245.4
AMORTISATION	127.9	CAP INV	146.5
DEBT INC	232.4	DIVIDEND	11.7
TOTAL	403.5	TOTAL	403.5

BALANCE SHEET FOR YEAR 1977

LAND &BLDG	521.3	EQUITY	233.8
M/C &EQPT	325.0	DEBT	882.9
TOOLING	256.1	RETAINED INCOME	1257.0
OTHER ASSETS	1271.2		
TOTAL	2373.7	TOTAL	2373.7

Company A

INCOME STATEMENT FOR YEAR 1977

SALES REVENUE		861.0
VARIABLE COSTS		768.2
FIXED COSTS		
SEL & ADM	92.8	
RES &DEV	24.0	
MAIN. TEL. & REN.	20.8	
RETIREMENT	16.5	
NON-INCOME TAX	17.3	
DEPRECIATION	7.8	
AMORTISATION	9.3	
INTEREST	9.5	
		198.0
PRE-TAX INCOME		-105.2
INCOME TAX		-31.6
AFTER-TAX INCOME		-73.7

CASH FLOW STATEMENT FOR YEAR 1977

SOURCES		USES	
DEPRECIATION	7.8	NET LOSS	73.7
AMORTISATION	9.3	CAP INV	31.1
DEBT INC	92.4	DIVIDEND	4.7
TOTAL	109.4	TOTAL	109.4

BALANCE SHEET FOR YEAR 1977

LAND &BLDG	46.5	EQUITY	39.2
M/C &EQPT	83.5	DEBT	183.7
TOOLING	27.8	RETAINED INCOME	133.0
OTHER ASSETS	197.1		
TOTAL	355.9	TOTAL	355.9

SUMMARY STATEMENT FOR YEAR 1977

	LARGE	MID-SIZE	COMPACT	SUBCOMPACT
MIX PRODUCED	0.189	0.268	0.225	0.317
MIX DESIRED	0.305	0.283	0.208	0.229
NEW PRICE	7921.	6315.	4747.	3866.

	Co. G	Co. F	Co. C	Co. A
SALE (MILLIONS)	5.106	2.330	1.390	0.213
BREAKEVEN (MIL.)	2.964	1.537	2.289	0.455
REVENUE	25368.	10690.	6116.	861.
NET INCOME	2109.	535.	-245.	-74.
CAP INV (TOT)	2293.	255.	146.	31.
CAP INV (AFES)	1400.	0.	16.	0.
NET CASH FLOW	159.	449.	-232.	-92.
DEBT	393.	278.	883.	184.
RET INCOME	8315.	3938.	1257.	133.
FUEL ECONOMY WITHOUT MIX SHIFTS	19.89	19.66	20.52	19.30

SUMMARY STATEMENT FOR YEAR 1978

	LARGE	MID-SIZE	COMPACT	SUBCOMPACT
MIX PRODUCED	0.191	0.270	0.226	0.314
MIX DESIRED	0.343	0.274	0.199	0.225
NEW PRICE	8206.	6137.	4690.	3953.

	Co. G	Co. F	Co. C	Co. A
SALE (MILLIONS)	5.281	2.409	1.439	0.221
BREAKEVEN (MIL.)	3.092	1.563	2.075	0.466
REVENUE	26191.	11065.	6289.	878.
NET INCOME	2333.	600.	-215.	-80.
CAP INV (TOT)	3109.	794.	499.	64.
CAP INV (AFES)	2216.	540.	368.	33.
NET CASH FLOW	114.	77.	-488.	-123.
DEBT	279.	201.	1370.	307.
RET INCOME	9828.	4403.	1031.	48.
FUEL ECONOMY WITHOUT MIX SHIFTS	20.49	19.86	20.78	19.47

SUMMARY STATEMENT FOR YEAR 1979

	LARGE	MID-SIZE	COMPACT	SUBCOMPACT
MIX PRODUCED	0.192	0.272	0.226	0.310
MIX DESIRED	0.339	0.252	0.210	0.227
NEW PRICE	8290.	5663.	4919.	4015.

	Co. G	Co. F	Co. C	Co. A
SALE (MILLIONS)	5.274	2.406	1.436	0.220
BREAKEVEN (MIL.)	3.007	1.531	1.830	0.328
REVENUE	25705.	11074.	6308.	899.
NET INCOME	2365.	725.	-155.	-54.
CAP INV (TOT)	1853.	1549.	323.	72.
CAP INV (AFES)	960.	1294.	192.	41.
NET CASH FLOW	1291.	-312.	-245.	-99.
DEBT	-1012.	513.	1615.	406.
RET INCOME	11372.	4992.	864.	-11.
FUEL ECONOMY WITHOUT MIX SHIFTS	20.75	20.53	20.90	20.13

SUMMARY STATEMENT FOR YEAR 1980

	LARGE	MID-SIZE	COMPACT	SUBCOMPACT
MIX PRODUCED	0.194	0.274	0.226	0.307
MIX DESIRED	0.333	0.254	0.219	0.213
NEW PRICE	8202.	5674.	4981.	3984.

	Co. G	Co. F	Co. C	Co. A
SALE (MILLIONS)	5.405	2.466	1.472	0.226
BREAKEVEN (MIL.)	2.908	1.436	1.789	0.275
REVENUE	26295.	11324.	6472.	928.
NET INCOME	2625.	914.	-126.	-35.
CAP INV (TOT)	1727.	888.	154.	183.
CAP INV (AFES)	834.	633.	23.	152.
NET CASH FLOW	1593.	559.	-79.	-165.
DEBT	-2604.	-46.	1694.	571.
RET INCOME	13176.	5770.	727.	-50.
FUEL ECONOMY WITHOUT MIX SHIFTS	20.94	20.81	20.90	20.86

SUMMARY STATEMENT FOR YEAR 1981

	LARGE	MID-SIZE	COMPACT	SUBCOMPACT
MIX PRODUCED	0.194	0.275	0.224	0.308
MIX DESIRED	0.337	0.258	0.230	0.196
NEW PRICE	8147.	5737.	5044.	3913.

	Co. G	Co. F	Co. C	Co. A
SALE (MILLIONS)	5.911	2.697	1.609	0.247
BREAKEVEN (MIL.)	3.034	1.482	1.678	0.278
REVENUE	28814.	12361.	7052.	991.
NET INCOME	3022.	1054.	-34.	-23.
CAP INV (TOT)	2029.	839.	800.	69.
CAP INV (AFES)	1136.	584.	669.	38.
NET CASH FLOW	1755.	754.	-507.	-38.
DEBT	-1360.	-800.	2201.	609.
RET INCOME	15377.	6688.	681.	-78.
FUEL ECONOMY WITHOUT MIX SHIFTS	22.00	21.95	21.62	21.02

SUMMARY STATEMENT FOR YEAR 1982

	LARGE	MID-SIZE	COMPACT	SUBCOMPACT
MIX PRODUCED	0.178	0.269	0.226	0.327
MIX DESIRED	0.341	0.257	0.227	0.198
NEW PRICE	8392.	5906.	5027.	3880.

	Co. G	Co. F	Co. C	Co. A
SALE (MILLIONS)	5.860	2.674	1.596	0.245
BREAKEVEN (MIL.)	2.897	1.404	1.660	0.290
REVENUE	28812.	12197.	6911.	930.
NET INCOME	3315.	1109.	-32.	-32.
CAP INV (TOT)	1729.	533.	299.	85.
CAP INV (AFES)	837.	279.	168.	54.
NET CASH FLOW	2296.	1053.	-29.	-61.
DEBT	-6655.	-1853.	2230.	670.
RET INCOME	17871.	7661.	638.	-114.
FUEL ECONOMY WITHOUT MIX SHIFTS	23.06	22.68	22.43	21.39

SUMMARY STATEMENT FOR YEAR 1983

	LARGE	MID-SIZE	COMPACT	SUBCOMPACT
MIX PRODUCED	0.150	0.256	0.235	0.359
MIX DESIRED	0.347	0.258	0.227	0.192
NEW PRICE	8835.	6367.	5002.	3786.

	Co. G	Co. F	Co. C	Co. A
SALE (MILLIONS)	5.761	2.628	1.569	0.241
BREAKEVEN (MIL.)	2.789	1.365	1.606	0.317
REVENUE	28772.	11861.	6731.	857.
NET INCOME	3561.	1150.	-19.	-49.
CAP INV (TOT)	1917.	541.	314.	77.
CAP INV (AFES)	1024.	287.	183.	46.
NET CASH FLOW	2399.	1048.	-44.	-69.
DEBT	-9055.	-2901.	2274.	739.
RET INCOME	20611.	8675.	607.	-168.
FUEL ECONOMY WITHOUT MIX SHIFTS	23.97	23.47	23.37	21.90

SUMMARY STATEMENT FOR YEAR 1984

	LARGE	MID-SIZE	COMPACT	SUBCOMPACT
MIX PRODUCED	0.130	0.245	0.244	0.380
MIX DESIRED	0.354	0.260	0.227	0.186
NEW PRICE	9197.	6794.	4952.	3715.

	Co. G	Co. F	Co. C	Co. A
SALE (MILLIONS)	5.849	2.669	1.593	0.244
BREAKEVEN (MIL.)	2.789	1.427	1.673	0.345
REVENUE	29411.	11880.	6929.	860.
NET INCOME	3832.	1136.	-41.	-60.
CAP INV (TOT)	2077.	832.	604.	67.
CAP INV (AFES)	1185.	577.	473.	36.
NET CASH FLOW	2595.	784.	-298.	-72.
DEBT	-11650.	-3685.	2573.	811.
RET INCOME	23622.	9675.	554.	-233.
FUEL ECONOMY WITHOUT MIX SHIFTS	24.92	24.59	24.94	22.84

Company G

INCOME STATEMENT FOR YEAR 1985

SALES REVNUE		29893.3
VARIABLE COSTS		16729.2
FIXED COSTS		
SEL & ADM	858.3	
RES &DEV	817.7	
MAIN, REP, & REA.	1636.5	
RETIREMENT	497.0	
NON-INCOME TAX	645.0	
DEPRECIATION	553.1	
AMORTISATION	936.5	
		5944.1
OPERATING PROFIT		7220.0
INTEREST EARNED		800.0
PRE-TAX INCOME		8020.0
INCOME TAX		3761.4
NET INCOME		4258.6

CASH FLOW STATEMENT FOR YEAR 1985

SOURCES		USES	
NET INCOME	4258.6	CAP INV	1393.7
DEPRECIATION	553.1	DIVIDEND	821.1
AMORTISATION	936.5	DEBT RED	3533.5
TOTAL	5748.2	TOTAL	5748.2

BALANCE SHEET FOR YEAR 1985

LAND &BLDG	2679.5	EQUITY	393.8
M/C & EQPT	4856.1	RETAINED INCOME	27059.6
TOOLING	936.5		
OTHER ASSETS	3796.0		
CREDITS	15183.5		
TOTAL	27453.4	TOTAL	27453.4

Company F

INCOME STATEMENT FOR YEAR 1985

SALES REVNUE		11945.5
VARIABLE COSTS		7758.7
FIXED COSTS		
SEL & ADM	474.2	
RES &DEV	364.6	
MAIN. REP. & REA.	360.4	
RETIREMENT	155.3	
NON-INCOME TAX	247.7	
DEPRECIATION	198.0	
AMORTISATION	391.9	
		2192.1
OPERATING PROFIT		1994.7
INTEREST EARNED		241.9
PRE-TAX INCOME		2236.6
INCOME TAX		1019.9
NET INCOME		1216.7

CASH FLOW STATEMENT FOR YEAR 1985

SOURCES		USES	
NET INCOME	1216.7	CAP INV	583.8
DEPRECIATION	198.0	DIVIDEND	135.8
AMORTISATION	391.9	DEBT RED	1087.1
TOTAL	1806.6	TOTAL	1806.6

BALANCE SHEET FOR YEAR 1985

LAND &BLDG	1097.2	EQUITY	121.8
M/C & EQPT	2300.0	RETAINED INCOME	10756.2
TOOLING	784.9		
OTHER ASSETS	1923.6		
CREDITS	4772.4		
TOTAL	10878.0	TOTAL	10878.0

Company C

INCOME STATEMENT FOR YEAR 1985

SALES REVNUE		7166.1
VARIABLE COSTS		5675.9
FIXED COSTS		
SEL & ADM	241.0	
RES &DEV	149.3	
MAIN. REP. & REA.	240.0	
RETIREMENT	110.3	
NON-INCOME TAX	111.8	
DEPRECIATION	99.0	
AMORTISATION	231.1	
INTEREST	223.6	
		1406.0
PRE-TAX INCOME		84.2
INCOME TAX		33.1
AFTER-TAX INCOME		51.1

CASH FLOW STATEMENT FOR YEAR 1985

SOURCES		USES	
NET INCOME	51.1	CAP INV	294.4
DEPRECIATION	99.0	DIVIDEND	11.7
AMORTISATION	231.1	DEBT RED	75.1
TOTAL	381.2	TOTAL	381.2

BALANCE SHEET FOR YEAR 1985

LAND &BLDG	641.2	EQUITY	233.8
M/C &EQPT	949.9	DEBT	2497.7
TOOLING	462.9	RETAINED INCOME	593.8
OTHER ASSETS	1271.2		
TOTAL	3325.2	TOTAL	3325.2

Company A

INCOME STATEMENT FOR YEAR 1985

SALES REVNUE		871.5
VARIABLE COSTS		659.0
FIXED COSTS		
SEL & ADM	93.2	
RES &DEV	24.1	
MAIN, REP, & REA.	21.0	
RETIREMENT	16.5	
NON-INCOME TAX	17.3	
DEPRECIATION	18.8	
AMORTISATION	39.8	
INTEREST	67.8	
		298.4
PRE-TAX INCOME		-85.9
INCOME TAX		-25.8
AFTER-TAX INCOME		-60.1

CASH FLOW STATEMENT FOR YEAR 1985

SOURCES		USES	
DEPRECIATION	18.8	NET LOSS	60.1
AMORTISATION	39.8	CAP INV	58.2
DEBT INC	64.4	DIVIDEND	4.7
TOTAL	123.0	TOTAL	123.0

BALANCE SHEET FOR YEAR 1985

LAND &BLDG	85.0	EQUITY	39.2
M/C &EQPT	215.4	DEBT	875.2
TOOLING	119.3		
OTHER ASSETS	197.1		
RETAINED LOSSES	297.6		
TOTAL	914.4	TOTAL	914.4

SUMMARY STATEMENT FOR YEAR 1985

	LARGE	MID-SIZE	COMPACT	SUBCOMPACT
MIX PRODUCED	0.114	0.233	0.252	0.402
MIX DESIRED	0.359	0.258	0.224	0.183
NEW PRICE	9569.	7184.	4947.	3689.

	Co. G	Co. F	Co. C	Co. A
SALE (MILLIONS)	5.939	2.710	1.617	0.248
BREAKEVEN (MIL.)	2.682	1.419	1.526	0.348
REVENUE	29893.	11945.	7166.	871.
NET INCOME	4259.	1217.	51.	-60.
CAP INV (TOT)	1394.	584.	294.	58.
CAP INV (AFES)	501.	329.	163.	27.
NET CASH FLOW	3534.	1087.	75.	-64.
DEBT	-15184.	-4772.	2498.	875.
RET INCOME	27060.	10756.	594.	-298.
FUEL ECONOMY WITHOUT MIX SHIFTS	25.15	25.11	25.14	24.15

APPENDIX B

Protocols for the Computer Program

To facilitate usage, the computer program has been written such that it can accept some data interactively, i.e., by the user inputing the data at the computer terminal rather than through a data file. When the program is run, the computer asks the user to specify some data. With reference to Protocol 1, the first four requests for data are self-explanatory. "Number of technological options" means measures such as improved lubricants, accessories, etc., but not downsizing and material substitution. In this context, there are six such options: automatic transmission, manual transmission, lubricants, accessories, aerodynamic drag and rolling resistance. Next, the computer asks whether the user requires deterministic analysis, as opposed to probabilistic analysis. If deterministic analysis is required the response is "Yes." The next three questions are self-explanatory.

If the user requires probabilistic analysis, he should respond "No" to the question "Require Deterministic Analysis?" In that case, the computer continues requesting data as in Protocol 2. The number of runs in the simulation is the number of separate trials in the Monte Carlo simulation. It was found that 50 trials are adequate. The odd integer number is to initially start off the random number generator. Next, the computer needs to know the distribution of the various fuel economy related variables. If the user responds "Yes," the computer assumes that the data is distributed according to a truncated normal distribution. If the user responds "No," the computer assumes that the distribution is uniform. Finally, there is a computer data file which contains the parameters of the distributions of the various variables as subjectively assessed by an industry expert. If the user responds "No" to the question "What to change data?" the computer will use the parameters from the available file. However, the user can change the parameters by responding "Yes" to the above question.

```
RUN AFES

SPECIFY OUTPUT DEVICE (5 FOR TTY,
3 FOR LPT) :   3

SPECIFY THE FIRST YEAR OF ANALYSIS :     77

SPECIFY THE LAST YEAR OF ANALYSIS:     85

SPECIFY SALES IN UNITS FOR GM, FORD, CHRYSLER, AMC
IN THAT ORDER FOR YEAR 1976 :    4.883E6,2.228E6,1.33E6,0.204E6

SPECIFY THE TOTAL NUMBER OF TECHNOLOGICAL OPTIONS USED :      6

REQUIRE DETERMINISTIC ANALYSIS?   YES

FINANCIAL STATEMENTS FOR WHICH FIRMS:   ALL

FINANCIAL STATEMENTS FOR WHICH YEARS:   77,85

SUMMARY STATEMENTS FOR WHICH YEARS:   ALL

EXIT
```

```
RUN AFES

SPECIFY OUTPUT DEVICE (5 FOR TTY,
3 FOR LPT) :   3

SPECIFY THE FIRST YEAR OF ANALYSIS :     77

SPECIFY THE LAST YEAR OF ANALYSIS:     85

SPECIFY SALES IN UNITS FOR GM, FORD, CHRYSLER, AMC
IN THAT ORDER FOR YEAR 1976 :   4.883E6,2.228E6,1.33E6,0.204E6

SPECIFY THE TOTAL NUMBER OF TECHNOLOGICAL OPTIONS USED :     6

REQUIRE DETERMINISTIC ANALYSIS?   NO

NUMBER OF RUNS IN THE SIMULATION  :   50

SUPPLY ANY ODD INTEGER NUMBER  :   579321

FUEL ECONOMY GAINS FROM TECHNOLOGICAL OPTIONS
DISTRIBUTED NORMALLY ?   YES

WANT TO CHANGE DATA?   NO

ADDITIONAL MANUFACTURING COSTS DUE TO TECHNOLOGICAL
OPTIONS DISTRIBUTED NORMALLY ?   YES

WANT TO CHANGE DATA?   NO

CAPITAL COSTS FOR TECHNOLOGICAL OPTIONS
DISTRIBUTED NORMALLY ?   YES

WANT TO CHANGE DATA?   NO

CAPITAL COSTS FOR DOWNSIZING DISTRIBUTED NORMALLY?   YES

WANT TO CHANGE DATA?   NO

CAPITAL COSTS FOR MATERIAL SUBSTITUTION DISTRIBUTED NORMALLY?   YES

WANT TO CHANGE DATA?   NO
```

APPENDIX C

Computer Data Files

The computer program for running the model requires six data files. The files are:

Name of Data File	Modules to which the file supplies data
MARKT.DAT	Market
FUELE.DAT	Fuel Economy
COSTS.DAT	Capital Costs, and Variable Manufacturing Costs
PRICE.DAT	Price
FINAN.DAT	Finance, and Proforma Generator
RANDM.DAT	Used only in the Probabilistic Case (contains the parameters of the probability distributions)

The data files in the format required by the computer program are given in this Appendix.

MARKT.DAT

```
0.0,0.0,0.2,0.8
0.5648,0.2577,0.1538,0.02359
76,10.2E6,0.2
77,11.3E6,0.2
78,11.6E6,0.194
79,11.5E6,0.188
80,11.7E6,0.182
81,12.7E6,0.176
82,12.5E6,0.170
83,12.2E6,0.164
84,12.3E6,0.158
85,12.4E6,0.152
86,12.2E6,0.150
```

```
18.0,19.0,21.0,25.0
16.5,17.0,20.0,24.0
15.5,16.0,18.0,31.0,
0.0,16.0,19.0,23.0
0.2742,0.4106,0.182,0.1332
0.2372,0.2382,0.224,0.3006
0.1338,0.2474,0.361,0.2578
0.0,0.1478,0.6655,0.1867
77,78,79,80
79,80,78,79
79,78,81,0
0,78,80,79
4158.0,3345.0,2838.0,2229.0
3837.0,3525.0,2899.0,2192.0
3911.0,3547.0,2956.0,2200.0
4000.0,3439.0,2864.0,2000.0
82,86,84,86
84,85,83,84
86,83,86,83
0,84,85,86
3645.0,3118.0,2629.0,2123.0
3556.0,3280.0,2673.0,2077.0,
3661.0,3286.0,2956.0,2050.0
4000.0,3239.0,2549.0,2000.0
4158.0,4073.0,3395.0,2587.0
4675.0,4217.0,3274.0,2508.0
4564.0,4184.0,3556.0,2200.0
4000.0,4107.0,3331.0,2970.0
0.10,0.05,0.02,0.02,0.04,0.03
77,17.0,0.0,0.0
0.0,0.0,0.0,0.0,0.0,0.0
0.0,0.0,0.0,0.0,0.0,0.0
0.0,0.0,0.0,0.0,0.0,0.0
0.0,0.0,0.0,0.0,0.0,0.0
78,18.0,0.0,0.0
0.0,0.0,0.0,0.0,0.0,0.0
0.0,0.0,0.0,0.0,0.0,0.0
0.0,0.0,0.0,0.0,0.0,0.0
0.0,0.0,0.0,0.0,0.0,0.0
79,19.0,0.0,0.0
0.0,0.0,0.0,0.0,0.0,0.0
0.0,0.0,0.0,0.0,0.0,0.0
0.0,0.0,0.0,0.0,0.0,0.0
0.0,0.0,0.0,0.0,0.0,0.0
80,20.0,0.0,0.0
0.0,0.0,0.0,0.0,0.0,0.0
0.0,0.0,0.0,0.0,0.0,0.0
0.0,0.0,0.0,0.0,0.0,0.0
0.0,0.0,0.0,0.0,0.0,0.0
81,22.0,0.0,0.01
0.2,0.07,0.2,0.2,0.6,0.2
0.25,0.05,0.2,0.2,0.6,0.2
0.0,0.0,0.2,0.0,0.3,0.2
0.0,0.0,0.2,0.0,0.2,0.2
82,24.0,0.0,0.01
0.4,0.07,0.4,0.4,0.7,0.4
0.4,0.10,0.4,0.4,0.7,0.4
0.1,0.05,0.4,0.2,0.6,0.4
0.0,0.0,0.4,0.0,0.4,0.4
83,26.0,0.0,0.01
0.65,0.07,0.60,0.60,0.8,0.6
0.5,0.15,0.6,0.6,0.8,0.6
0.15,0.15,0.6,0.4,0.7,0.6
0.0,0.05,0.6,0.2,0.6,0.6
84,27.0,0.0,0.01
0.9,0.07,0.8,0.8,0.8,0.8
0.75,0.15,0.8,0.8,0.8,0.8
0.7,0.15,0.8,0.6,0.8,0.8
0.25,0.10,0.8,0.4,0.7,0.7
85,27.5,0.0,0.01
0.93,0.07,1.00,1.0,0.8,0.8
0.85,0.15,1.0,1.0,0.8,0.8
0.85,0.15,1.0,0.8,0.8,0.8
0.4,0.13,1.0,0.6,0.8,0.8
```

COSTS.DAT

```
1000.0,50.0,500.0,25.0,0.0,25.0,0.0,0.0
0.5093,0.715,0.8305,0.858
1175.0,775.0,1050.0,713.0
45.0,25.0,5.0,10.0,10.0,35.0
```

```
5488. 0,6534. 0,5316. 0,4686. 0,4030. 0
76,0. 24676,0. 30895,0. 21065,0. 23673
77,0. 30539,0. 28284,0. 20803,0 22853
78,0. 3432897,0. 2742,0. 19896,0. 2247
79,0. 3389,0. 252441,0. 20966,0. 22696
80,0. 33308,0. 25363,0. 21899,0. 21288
81,0. 33696,0 2583,0. 2297,0. 19605
82,0. 34069,0. 256798,0. 2271,0 19848
83,0. 34727,0 25815,0. 2274,0 1916
84,0. 35397,0. 2596,0. 2267,0 1857
85,0. 35945,0. 25777,0. 22388,0. 1828
86,0. 352736,0. 261477,0. 2235,0 1876
```

```
1.639E9,869.0E6,517.4E6,43.656E6
2.146E9,1143.8E6,307.3E6,80.109E6
391.2E6,451.2E6,302.4E6,20.994E6
3.796E9,1923.6E6,1271.2E6,197.119E6
0.3938E9,121.76E6,233.76E6,39.18E6
0.5512E9,726.97E6,650.48E6,91.288E6
7.027E9,3.5388E9,1514.06E6,211.39E6
154.7E6,31.36E6,19.275E6,4.313E6
278.0E6,87.37E6,39.38E6,10.71E6
460.0E6,136.0E6,72.27E6,16.06E6
0.04,0.03,0.03,0.03
0.0833,0.0666,0.0769,0.07
0.5,0.333,0.333,0.25
0.078,0.078,0.078,0.078
0.469,0.456,0.393,0.3
2.085,1.115,0.05,0.12
760.0E6,358.8E6,225.75E6,96.75E6
707.0E6,414.69E6,145.2E6,24.3E6
1510.0E6,326.37E6,235.5E6,26.4E6
497.0E6,155.25E6,110.25E6,16.5E6
645.0E6,247.71E6,111.75E6,17.3E6
0.0,0.3,0.4,0.56,0.67
```

RANDM.DAT

```
0.0375,0.1,0.03,0.122
0.0375,0.05,0.00625,0.0625
0.0,0.02,0.006,0.025
0.0075,0.02,0.00625,0.0325
0.0067,0.04,0.0167,0.045
0.013,0.03,0.0085,0.047
35.0,45.0,12.0,70.0
19.4,25.0,2.8,30.6
4.45,5.0,0.3,5.55
7.5,10.0,5.5,21.0
7.5,10.0,5.5,21.0
26.25,35.0,19.4,74.0
750.0,1000.0,550.0,2100.0
37.5,50.0,27.5,105.0
375.0,500.0,275.0,1050.0
18.75,25.0,13.75,52.5
0.0,0.0,0.0,0.0
18.75,25.0,13.75,52.5
0.0,0.0,0.0,0.0
0.0,0.0,0.0,0.0
```

APPENDIX D

Computer Program

```
C         AUTO INDUSTRY RISK ANALYSIS
C         PRELIMINARY PART OF MARKET MODULE
          DIMENSION FSIZE(4),D4SHRE(4),SALE(4),PRESAL(4),XPRESA(4)
          DIMENSION IPR(10),JPR(4),ISUM(10),ARRAY(100)
          DIMENSION SIMHYP (100,4),HYPDAV(4),FUELMI(10),FUELMA(10),
          9ACMINI(10),ACMAXI(10),CCMINI(10),CCMAXI(10),DOWMN(1),
          9DOWDEV(1),SUBMN(1),SUBDEV(1),DOWMIN(1),DOWMAX(1),
          9SUBMIN(1),SUBMAX(1)
C         INTERACTIVE DATA INPUT
          NRAN=1
          NMKT=20
          NFUEL=21
          NCOST=22
          NPRICE=23
          NFIN=24
          CALL PREDAT (NMKT,IPR,JPR,ISUM
          9,NSTART,NFIN,PRESAL,NOPT,IDFI)
          DO 1500 J=1,4
1500      XPRESA(J)=PRESAL(J)
          DIMENSION FGMEAN(10),FGDEV(10),ACOMN(10),ACODEV(10),
          9CCOMN(10),CCODEV(10)
          IF (IDFI-1)750,751,750
751       NTIME=1
          GO TO 752
750       CALL IFILE (NRAN,'RANDF.DAT')
          READ (NRAN,3000) (FUELMI(L),FGMEAN(L),FGDEV(L),
          9FUELMA(L),L=1,NOPT),(ACMINI(L),ACOMN(L),ACODEV(L),
          9ACMAXI(L),L=1,NOPT),DOWMIN,DOWMN,DOWDEV,DOWMAX,
          9SUBMIN,SUBMN,SUBDEV,SUBMAX
          9,(CCMINI(L),CCOMN(L),CCODEV(L),CCMAXI(L),L=1,NOPT)
3000      FORMAT (4F)
          CALL PREIDF (NTIME,IX,FGMEAN,FGDEV,DESYMN,DESYDV,
          9ACOMN,ACODEV,CCOMN,CCODEV,IFN,IDN,IACON,ICCON,
          9DOWMN,DOWMIN,DOWMAX,SUBMIN,SUBMAX,DOWDEV,IDOWN,
          9SUBMN,SUBDEV,ISUBN,FUELMI,FUELMA,ACMINI,ACMAXI,
          9CCMINI,CCMAXI,NOPT)
752       DO 10 NT=1,NTIME
          CALL IFILE (NMKT,'MARKT.DAT')
          READ (NMKT,500)FSIZE,D4SHRE
500       FORMAT (4F/4F)
C         PRELIMINARY PART OF FUEL ECONOMY MODULE
          DIMENSION CFUEL(4,4),NTIMWT(4,4),WIDN(4,4),NTIMMT(4,4)
          9,WIMTL(4,4),WEIGHT(4,4),FUELGA(10),TECHOF(10,4)
          9,CPMIX(4,4),XNPMIX(4,4),BFUEL(4),PRETEC(10,4),XCPMIX(4,4)
          CALL IFILE (NFUEL,'FUELE.DAT')
          READ (NFUEL,601) CFUEL,CPMIX,NTIMWT,WIDN,NTIMMT,
          9WIMTL,WEIGHT,(FUELGA(NUM),NUM=1,NOPT)
601       FORMAT(8(4F/),4(4I/),4(4F/),4(4I/),8(4F/),15F)
          DO 1501 J=1,4
          DO 1501 K=1,4
1501      XCPMIX(K,J)=CPMIX(K,J)
C         PRELIMINARY PART OF THE CAPITAL COSTS MODULE
          DIMENSION CCOST(10),CAPFE(4)
          CALL IFILE (NCOST,'COSTS.DAT')
          READ (NCOST,550) CCODOW,CCOMTL,(CCOST(NUM),NUM=1,NOPT)
550       FORMAT (15F)
C         PRELIMINARY PART OF THE MANUFACTURING COSTS MODULE
          DIMENSION ACOST(10),XMCOST(4),XLCOST(4),TVARCO(4)
          READ (NCOST,590) XMCOST,XLCOST,(ACOST(NUM),NUM=1,NOPT)
590       FORMAT (4F/4F/15F)
```

```
C       PRELIMINARY PART OF THE PRICE MODULE
        DIMENSION XMKTMX(4),CURPRC(4),ACTMIX(4),ACTPRC(4),
        9OLDCPM(4),ACTCPM(4)
        CALL IFILE (NPRICE,'PRICE.DAT')
        READ (NPRICE,700) AVPRC,CURPRC
700     FORMAT (5F)
C       PRELIMINARY PART OF THE FINANCIAL MODULE
        DIMENSION BVLNB(4),BVMNE(4),BVTOOL(4),EQUITY(4),DEBT(4),
        9ANNLNB(4),ANNMNE(4),ANNTOL(4),DEPLNB(4),AMOPER(4),RETPRO(4),
        9DEPMNE(4),RATINT(4),TAXRAT(4),DIVDND(4),OTHCAP(4)
        9,SIMDEB(100,4),SIMRETZ(100,4),SIMPRO(100,4)
        CALL IFILE (NFIN,'FINAN.DAT')
        READ(NFIN,710)BVLNB,BVMNE,BVTOOL,OTHCAP,EQUITY,DEBT,RETPRO,
        9ANNLNB,ANNMNE,ANNTOL,DEPLNB,DEPMNE,AMOPER,RATINT,
        9TAXRAT,DIVDND
710     FORMAT (10(4E/),5(4F/),4F)
C       PRELIMINARY PART OF THE PROFORMA GENERATOR
        DIMENSION SNA(4),RND(4),XMRR(4),RET(4),OTHTAX(4)
3001    READ (NFIN,720) SNA,RND,XMRR,RET,OTHTAX
720     FORMAT (5(4E/))
        IF (IDET=1) 753,754,753
753     DO 758 NUM=1,NOPT
        IF (IFN=1)755,756,755
756     CALL GAUSS (IX,FGDEV(NUM),FGMEAN(NUM),FUELMI(NUM)
        9,FUELMA(NUM),FUELGA(NUM))
        GO TO 757
755     CALL UNIFO (IX,FUELMA(NUM),FUELMI(NUM),FUELGA(NUM))
757     IF (IACON=1)759,760,759
760     CALL GAUSS (IX,ACODEV(NUM),ACOMN(NUM)
        9,ACMINI(NUM),ACMAXI(NUM),ACOST(NUM))
        GO TO 761
759     CALL UNIFO (IX,ACMAXI(NUM),ACMINI(NUM),ACOST(NUM))
761     IF (ICCON=1)762,763,762
763     CALL GAUSS (IX,CCODEV(NUM),CCOMN(NUM),CCMINI(NUM),
        9CCMAXI(NUM),CCOST(NUM))
        GO TO 758
762     CALL UNIFO (IX,CCMAXI(NUM),CCMINI(NUM),CCOST(NUM))
758     CONTINUE
764     IF (IDOWN=1)770,771,770
771     CALL GAUSS(IX,DOWDEV,DOWMN,DOWMIN,DOWMAX,CCODOW)
        GO TO 772
770     CALL UNIFO (IX,DOWMAX,DOWMIN,CCODOW)
772     IF(ISUBM=1)773,774,773
774     CALL GAUSS (IX,SUBDEV,SUBMN,SUBMIN,SUBMAX,CCOMTL)
        GO TO 754
773     CALL UNIFO (IX,SUBMAX,SUBMIN,CCOMTL)
C       CONTROLLING PART OF THE PROGRAM
C       INITIALISATION
754     DO 8 J=1,4
        DO 8 ITO=1,NOPT
8       PRETEC(ITO,J)=0
        DO 790 J=1,4
        PRESAL(J)=XPRESA(J)
        DO 790 K=1,4
790     CPMIX(K,J)=XCPMIX(K,J)
        DO 10 NYEAR=NSTART,NEND
        CALL MARKET(NMKT,NWRT,NYEAR,FSALE,SALE,DMSHRE,*25,TSALE)
        GO TO 5
25      WRITE(NWRT,504)NYEAR
504     FORMAT ('  DATA FOR YEAR 19',I2,' IS NOT AVAILABLE')
```

```
      GO TO 2000
5     CALL FUEL (*25,CFUEL,CPMIX,NTIMWT,WTDN,NTIMMT,WTMTL,
     9WEIGHT,FUELGA,TECHOP,NFUEL,NWRT,NYEAR,XNPMIX,NOPT,HYPOAV,XCPMIX)
      CALL CAPCOS (NWRT,CAPFE,TECHOP,SALE,PRETEC,PRESAL,CCOST,
     9XNPMIX,CCWDN,NTIMWT,NTIMMT,CCOMTL,NYEAR,NOPT,CPMIX)
      CALL MANCOS (NWRT,NYEAR,NTIMWT,NTIMMT,WEIGHT,
     9WTDN,WTMTL,XNPMIX,SALE,AMCOST,XLCOST,
     9NOPT,ACOST,TECHOP,TVARCO)
      CALL PRICE (*25,NPRICE,NYEAR,NWRT,FSALE,FSIZE,
     9XNPMIX,SALE,CURPRC,ACTPRC,AVPRC,TSALE,ACTMIX,XMKTMX)
      DO 6 J=1,4
      CALL FINANC (BVLNB,CAPFE,ANNLNB,BVMNE,ANNMNE,
     9BVTOOL,ANNTOL,DEBT,DEPLNB,DEPMNE,AMOPER,RATINT
     9,EQUITY,DIVDNP,DEP,AMORT,ENTRST,DIV,J,NWRT)
6     CALL PROFRM (J,NWRT,XNPMIX,ACTPRC,SNA,DIV,SALE,
     9RND,XMRF,RET,OTHTAX,DEP,AMORT,ENTRST,TVARCO,TAXRAT,
     9CAPFE,ANNLNB,ANNMNE,ANNTOL,DEBT,NYEAR,EQUITY,OTHCAP,RETPRO,
     9BVLNB,BVMNE,BVTOOL,IPR,JPR,ISUM,ACTMIX,XMKTMX,NEND,
     9IDET,SIMDEB,SIMRET,SIMPRO,NT,HYPOAV,SIMHYP)
C     RETAINING PREVIOUS YEAR DATA
      DO 80 J=1,4
      PRESAL(J)=SALE(J)
      DO 81 K=1,4
81    CPMIX(K,J)=XNPMIX(K,J)
      DO 80 ITO=1,NOPT
80    PRETEC(ITO,J)=TECHOP(ITO,J)
10    CONTINUE
      IF (IDET-1)1900,2000,1900
1900  WRITE (NWRT,1901)NEND
1901  FORMAT (1H1,T20,' POSITION AT END OF YEAR 19',I2///
     9T40,'FRACTILES'/T30,'0.10',T40,'0.25',T50,'0.50',
     9T60,'0.75',T70,'0.90'//)
      DO 2800 J=1,4
      GO TO (1902,1903,1904,1905)J
1902  WRITE (NWRT,2902)
2902  FORMAT (T2,'GENERAL MOTORS')
      GO TO 1906
1903  WRITE (NWRT,2903)
2903  FORMAT (T2,'FORD')
      GO TO 1906
1904  WRITE (NWRT,2904)
2904  FORMAT (T2,'CHRYSLER')
      GO TO 1906
1905  WRITE (NWRT,2905)
2905  FORMAT (T2,'AMC')
1906  DO 1907 NX=1,NTIME
1907  ARRAY(NX)=SIMDEB(NX,J)
      CALL SIMULA (NTIME,ARRAY,FRA10,FRA25,FRA50,FRA75,FRA90)
      WRITE (NWRT,1908) FRA10,FRA25,FRA50,FRA75,FRA90
1908  FORMAT (T7,'DEBT',T27,F8.0,T37,F8.0,T47,F8.0,
     9T57,F8.0,T65,F8.0)
      DO 1909 NX=1,NTIME
1909  ARRAY(NX)=SIMRET(NX,J)
      CALL SIMULA (NTIME,ARRAY,FRA10,FRA25,FRA50,FRA75,FRA90)
      WRITE (NWRT,1910)FRA10,FRA25,FRA50,FRA75,FRA90
1910  FORMAT (T7,'RET INCOME',T27,F8.0,T37,F8.0,T47,F8.0,
     9T57,F8.0,T65,F8.0)
      DO 1911 NX=1,NTIME
1911  ARRAY (NX)=SIMPRO(NX,J)
      CALL SIMULA (NTIME,ARRAY,FRA10,FRA25,FRA50,FRA75,FRA90)
```

```
      WRITE (NWRT,1912)FRA10,FRA25,FRA50,FRA75,FRA90
1912  FORMAT (T7,'AFT-TAX PROFIT',T27,F8.0,T37,F8.0,T47,F8.0,
     9T57,F8.0,T65,F8.0)
      DO 1930 NX=1,NTIME
1930  ARRAY(NX)=SIMHYP(NX,J)
      CALL SIMULA (NTIME,ARRAY,FRA10,FRA25,FRA50,FRA75,FRA90)
      WRITE (NWRT,1931) FRA10,FRA25,FRA50,FRA75,FRA90
1931  FORMAT (T7,'FUEL ECONOMY WITHOUT'/T7,'MIX SHIFTS',T27,
     9F8.2,T37,F8.2,T47,F8.2,T57,F8.2,T65,F8.2///)
2800  CONTINUE
2000  STOP
      END
```

```
      SUBROUTINE PREDAT (NWRT,IPR,JPR,ISUM,
     9NSTART,NEND,PRESAL,NOPT,IDET)
      DIMENSION PRESAL(4),IPR(4),JPR(10),ISUM(10)
103   FORMAT (' INCORRECT RESPONSE')
109   WRITE(5,106)
106   FORMAT (' SPECIFY OUTPUT DEVICE (5 FOR TTY,'/
     9' 3 FOR LPT) :',3X,$)
      CALL ANSWEX (2,IA,NWRT)
      IF (IA-4) 107,108,107
107   WRITE (5,103)
      GO TO 109
108   WRITE (5,110)
110   FORMAT (' SPECIFY THE FIRST YEAR OF ANALYSIS :',5X,$)
      CALL ANSWEX (2,IA,NSTART)
      IF (IA-4)111,112,111
111   WRITE (5,103)
      GO TO 108
112   WRITE (5,113)
113   FORMAT (' SPECIFY THE LAST YEAR OF ANALYSIS:',5X,$)
      CALL ANSWEX (2,IA,NEND)
      IF (IA-4)114,115,114
114   WRITE(5,103)
      GO TO 112
115   IF (NSTART-1900)116,117,117
117   NSTART=NSTART-1900
      NEND=NEND-1900
116   NY=NSTART-1+1900
118   WRITE (5,119) NY
119   FORMAT (' SPECIFY SALES IN UNITS FOR GM, FORD,
     9 CHRYSLER, AMC '/' IN THAT ORDER FOR YEAR ',I4,' :',3X,$)
      CALL ANSWEX (7,IA,NORX)
      IF (IA-4)120,121,120
120   WRITE (5,103)
      GO TO 118
121   IF (NORX-4) 122,123,122
122   WRITE (5,103)
      GO TO 118
123   CALL INDLIS (4,0,0,1,DEIL,IA,NORX,PRESAL)
125   WRITE (5,124)
124   FORMAT (' SPECIFY THE TOTAL NUMBER OF TECHNOLOGICAL
     9 OPTIONS USED :',5X,$)
      CALL ANSWEX (2,IA,NOPT)
      IF (IA-4)126,127,126
126   WRITE (5,103)
      GO TO 125
127   WRITE (5,153)
153   FORMAT (' REQUIRE DETERMINISTIC ANALYSIS?',3X,$)
      CALL ANSWEX (0,IDET,NORX)
      IF(IDET-1)140,1127,140
1127  DO 1136 L=1,10
      ISUM(L)=0
1136  IPR(L)=0
138   WRITE(5,150)
150   FORMAT(' FINANCIAL STATEMENTS FOR WHICH FIRMS:',3X,$)
      CALL ANSWEX (7,IA,NORX)
      IF (NORX) 128,129,128
129   DO 130 L=1,4
130   JPR(L)=1
      GO TO 131
128   IF (NORX-4) 137,139,137
```

```
137     WRITE (5,103)
        GO TO 136
139     CALL INPUTS (4,6,1,IA,NOEX,IPR)
131     WRITE (5,151)
151      FORMAT (' FINANCIAL STATEMENTS FOR WHICH YEARS:',3X,$)
        CALL ANSWER (7,IA,NOEX)
        IF (NOEX) 132,133,132
133     IPR(1)=99
        GO TO 134
132     CALL INPUTS (10,70,90,IA,NOEX,IPR)
134     WRITE (5,152)
152     FORMAT (' SUMMARY STATEMENTS FOR WHICH YEARS:',3X,$)
        CALL ANSWER (7,IA,NOEX)
        IF (NOEX) 135,136,135
136     ISUM(1)=99
        GO TO 140
135     CALL INPUTS (10,70,90,IA,NOEX,ISUM)
140     RETURN
```

```
      SUBROUTINE PREINF (NTIME,IX,FGMEAN,FGDEV,DESYMN,DESYDV,
     9ACOMN,ACODEV,CCOMN,CCODEV,IFN,IDN,IACON,ICCON,DOWMN,
     9DOWMIN,DOWMAX,SUBMIN,SUBMAX,DOWDEV,IDOWN,SUBMN,SUBDEV,
     9ISUBN,FUELMI,FUELMA,ACMINI,ACMAXI,CCMINI,CCMAXI,NOPT)
      DIMENSION FGMEAN(10),FGDEV(10),ACOMN(10),ACODEV(10),
     9CCOMN(10),CCODEV(10),FUELMI(10),FUELMA(10),ACMINI(10),
     9ACMAXI(10),CCMINI(10),CCMAXI(10),DOWMN(1),DOWDEV(1),
     9SUBMN(1),SUBDEV(1),DOWMIN(1),DOWMAX(1),SUBMIN(1),
     9SUBMAX(1)
      WRITE (5,780)
780   FORMAT (' NUMBER OF RUNS IN THE SIMULATION  :',3X,$)
      CALL ANSWEX (2,IA,NTIME)
      WRITE (5,781)
781   FORMAT (' SUPPLY ANY ODD INTEGER NUMBER  :',3X,$)
      CALL ANSWEX (2,IA,IX)
      WRITE (5,782)
782   FORMAT (' FUEL ECONOMY GAINS FROM TECHNOLOGICAL OPTIONS'/
     9' DISTRIBUTED NORMALLY ?',3X,$)
      CALL ANSWEX (0,IFN,NORX)
      CALL SUBINF (IFN,FGMEAN,FGDEV,FUELMI,FUELMA,NOPT)
      WRITE (5,785)
785   FORMAT (' ADDITIONAL MANUFACTURING COSTS DUE TO TECHNOLOGICAL'
     9/' OPTIONS DISTRIBUTED NORMALLY ?',3X,$)
      CALL ANSWEX (0,IACON,NORX)
      CALL SUBINF (IACON,ACOMN,ACODEV,ACMINI,ACMAXI,NOPT)
      WRITE (5,788)
788   FORMAT (' CAPITAL COSTS FOR TECHNOLOGICAL OPTIONS'/
     9' DISTRIBUTED NORMALLY ?',3X,$)
      CALL ANSWEX (0,ICCON,NORX)
      CALL SUBINF (ICCON,CCOMN,CCODEV,CCMINI,CCMAXI,NOPT)
      WRITE (5,10)
10    FORMAT (' CAPITAL COSTS FOR DOWNSIZING DISTRIBUTED NORMA
     9LLY?',3X,$)
      CALL ANSWEX (0,IDOWN,NORX)
      N=1
      CALL SUBINF (IDOWN,DOWMN,DOWDEV,DOWMIN,DOWMAX,N)
      WRITE (5,11)
11    FORMAT (' CAPITAL COSTS FOR MATERIAL SUBSTITUTION DISTRIBUTED
     9 NORMALLY?', 3X, $)
      CALL ANSWEX (0,ISUBN,NORX)
      N=1
      CALL SUBINF (ISUBN,SUBMN,SUBDEV,SUBMIN,SUBMAX,N)
      RETURN
```

```
      SUBROUTINE SUBINF (I,XMEAN,DEV,XMIN,XMAX,N)
      DIMENSION XMEAN(N),DEV(N),XMIN(N),XMAX(N)
2     WRITE (5,1)
1     FORMAT (' WANT TO CHANGE DATA?', 3X,$)
      CALL ANSWEX (0,IDUM,NORX)
      IF (IDUM-1)3,4,2
4     IF (I-1)5,6,5
6     WRITE(5,7)N
7     FORMAT (' MEAN VALUES FOR ',I1,' PARAMETERS:',3X,$)
      CALL ANSWEX (7,IA,NORX)
      CALL INDLIS (10,0,0,1,0E5,IA,NORX,XMEAN)
      IF (NORX-0)6,8,6
8     WRITE (5,9)N
9     FORMAT (' STD. DEV. FOR ',I1,' PARAMETERS:',3X,$)
      CALL ANSWEX (7,IA,NORX)
      CALL INDLIS (10,0,0,1,0E5,IA,NORX,DEV)
      IF (NORX-0)8,3,8
5     WRITE (5,10)N
10    FORMAT (' MINIMUM VALUES FOR ',I1,' PARAMETERS:',3X,$)
      CALL ANSWEX (7,IA,NORX)
      CALL INDLIS(10,0,0,1,0E5,IA,NORX,XMIN)
      IF (NORX-0)5,11,5
11    WRITE (5,12)N
12    FORMAT (' MAXIMUM VALUES FOR ',I1,' PARAMETERS:',3X,$)
      CALL ANSWEX (7,IA,NORX)
      CALL INDLIS (10,0,0,1,0E5,IA,NORX,XMAX)
      IF (NORX-0)11,3,11
3     RETURN
```

```
51      SUBROUTINE GAUSS(IX,S,AM,XMIN,XMAX,V)
        A=0.0
        DO 50 I=1,12
50      CALL RANDU (IX,Y)
        A=A+Y
        V=(A-6.0)*S+AM
52      IF(V-XMIN)51,52,52
53      IF(V-XMAX)53,53,51
        RETURN
```

```
      SUBROUTINE RANDU (IX,YFL)
      IY=IX*65539
      IF(IY)5,6,6
5     IY=IY+34359738367+1
6     YFL=IY
      YFL=YFL*0.2910383E-10
      IX=IY
      RETURN
```

```
SUBROUTINE UNIFO(IX,XMAX,XMIN,V)
CALL RANDU(IX,Y)
V=XMIN+Y*(XMAX-XMIN)
RETURN
```

```
        SUBROUTINE MARKET (NMKT,NWRT,NYEAR,FSALE,SALE,DMSHRE,S,TSALE)
        DIMENSION SALE(4),DMSHRE(4)
1       READ (NMKT,501) NOW,TSALE,FMSHRE
501     FORMAT (I,E,F)
        IF (NYEAR-NOW) 26,2,1
2       FSALE=TSALE*FMSHRE
        DO 3 I=1,1
3       SALE(I)=(TSALE-FSALE)*DMSHRE(J)
        RETURN
26      RETURN 7
```

```
      SUBROUTINE FUEL (*,CFUEL,CPMIX,NTIMWT,WTDN,NTIMMT,WTMTL,WEIGHT,
     9FUELGA,TECHOP,NFUEL,NWRT,NYEAR,XNPMIX,NOPT,
     9HYPOAV,XCPMIX)
      DIMENSION CFUEL(4,4),NTIMWT(4,4),WTDN(4,4),NTIMMT(4,4)
     9,WTMTL(4,4),WEIGHT(4,4),FUELGA(10),TECHOP(10,4),
     9CPMIX(4,4),XNPMIX(4,4),BFUEL(4),HYPOAV(4),XCPMIX(4,4)
20    READ (NFUEL,602,ERR=27)NOW,AFES,EMISS,
     9SAFETY,((TECHOP(NUM,J),NUM=1,NOPT),J=1,4)
602   FORMAT (I,3F/3(6F/),6F)
C     CALCULATE WEIGHT OF CAR BY SIZE AND BY MANUFACTURER AND
C     FUEL CONSUMPTION CONSIDERING CHANGE IN WEIGHT ONLY
      IF (NYEAR-NOW) 27,30,20
30    DO 60 J=1,4
      DO 50 K=1,4
      IF (NYEAR-NTIMWT(K,J))31,32,32
32    IF (NYEAR-NTIMMT(K,J))33,34,34
31    BFUEL(K)=CFUEL(K,J)
      GO TO 50
33    DUMMY=(WTDN(K,J)+300.0)/(WEIGHT(K,J)+300.0)
      GO TO 35
34    DUMMY=(WTMTL(K,J)+300.0)/(WEIGHT(K,J)+300.0)
35    BFUEL(K)=CFUEL(K,J)*(0.575/DUMMY**0.470768
     9+0.425/DUMMY**0.314598)
50    CONTINUE
C     CALCULATE EFFECT OF TECHNOLOGICAL OPTIONS AND SAFETY
C     AND EMISSION REGULATIONS ON FUEL CONSUMPTION
      DUMMY=0
      DO 40 ITO=1,NOPT
40    DUMMY=DUMMY+FUELGA(ITO)*TECHOP(ITO,J)
      DUMMY=(1.0+DUMMY)*(1.0-SAFETY-EMISS)
      AVFUEL=0
      DO 41 K=1,4
41    AVFUEL=AVFUEL+BFUEL(K)*CPMIX(K,J)
      AVFUEL=AVFUEL*DUMMY
      HYPOAV(J)=0.0
      DO 90 K=1,4
90    HYPOAV(J)=HYPOAV(J)+BFUEL(K)*XCPMIX(K,J)
      HYPOAV(J)=HYPOAV(J)*DUMMY
C     COMPARE FLEET WEIGHTED AVERAGE FUEL CONSUMPTION
C     WITH STANDARD SET
      IF (AVFUEL-AFES) 43,42,42
C     NO MIX CHANGE
42    DO 44 K=1,4
44    XNPMIX(K,J)=CPMIX(K,J)
      GO TO 60
C     CALCULATE MIX CHANGE
43    CHANGE= (AFES-AVFUEL)/DUMMY
      DUM=CPMIX(1,J)*BFUEL(1)+(CPMIX(1,J)-CPMIX(2,J))*BFUEL(2)
     9+(CPMIX(2,J)-CPMIX(3,J))*BFUEL(3)
     9+CPMIX(3,J)*BFUEL(4)
      CHANGE=CHANGE/DUM
C     CALCULATE NEW PRODUCT MIX FOR MANUFACTURER J
      XNPMIX(4,J)=CHANGE*CPMIX(3,J)+CPMIX(4,J)
      XNPMIX(3,J)=CHANGE*(CPMIX(2,J)-CPMIX(3,J))+CPMIX(3,J)
      XNPMIX(2,J)=CHANGE*(CPMIX(1,J)-CPMIX(2,J))+CPMIX(2,J)
      XNPMIX(1,J)=CPMIX(1,J)*(1.0-CHANGE)
60    CONTINUE
      RETURN
27    RETURN 1
```

```
      SUBROUTINE CAPCOS (NMRT,CAPFE,TECHOP,SALE,PRETEC,PRESAL,CCOST,
     9XNPMIX,CCODOW,NTIMWT,NTIMMT,CCOMTL,NYEAR,NOPT,CPMIX)
      DIMENSION CCOST(10),CAPFE(4),TECHOP(10,4),SALE(4),
     9PRETEC(10,4),PRESAL(4),NTIMWT(4,4),NTIMMT(4,4),
     9CPMIX(4,4),XNPMIX(4,4)
      DO 70 J=1,4
      CAPDN=0
      CAPOP=0
      CAPMT=0
C     CAPITAL COST OF IMPLEMENTING TECHNOLOGICAL OPTIONS FOR
C     MANUFACTURER  J
      DO 71 ITO=1,NOPT
71    CAPOP=CAPOP+(TECHOP(ITO,J)*SALE(J)-PRETEC(ITO,J)
     9*PRESAL(J))*CCOST(ITO)
      DO 72 K=1,4
C     CAPITAL COST FOR DOWNSIZING
      IF (NYEAR-NTIMWT(K,J)) 72,74,75
74    CAPDN=CAPDN+XNPMIX(K,J)*SALE(J)*CCODOW
      GO TO 72
75    DUMMY=XNPMIX(K,J)*SALE(J)-CPMIX(K,J)*PRESAL(J)
      IF (DUMMY) 72,72,175
175   CAPDN=CAPDN+(XNPMIX(K,J)*SALE(J)-CPMIX(K,J)
     9*PRESAL(J))*CCODOW
72    CONTINUE
C     CAPITAL COST FOR MATERIAL SUBSTITUTION
      DO 76 K=1,4
      IF (NYEAR-NTIMMT(K,J))76,77,78
77    CAPMT=CAPMT+XNPMIX(K,J)*SALE(J)*CCOMTL
      GO TO 76
78    DUMMY=XNPMIX(K,J)*SALE(J)-CPMIX(K,J)*PRESAL(J)
      IF (DUMMY) 76,76,178
178   CAPMT=CAPMT+(XNPMIX(K,J)*SALE(J)-CPMIX(K,J)
     9*PRESAL(J))*CCOMTL
76    CONTINUE
C     CALCULATE TOTAL CAPITAL INVESTMENT DUE TO FUEL ECONOMY
C     REGULATIONS FOR MANUFACTURER  J
      CAPFE(J)=CAPOP+CAPDN+CAPMT
70     CONTINUE
      RETURN
```

```
      SUBROUTINE MANCOS (NWRT,NYEAR,NTIMWT,NTIMMT,WEIGHT,WTON,WTMTL,
     9XNPMIX,SALE,XMCOST,XLCOST,NOPT,ACUST,TECHOP,TVARCO)
      DIMENSION ACOST(10),XMCOST(4),XLCOST(4),TVARCO(4),
     9NTIMWT(4,4),NTIMMT(4,4),WEIGHT(4,4),WTON(4,4),
     9WTMTL(4,4),XNPMIX(4,4),SALF(4),TECHOP(10,4)
      DO 200 J=1,4
      TMCOST=0
      TACOST=0
      DO 201 K=1,4
      IF (NYEAR-NTIMWT(K,J))202,203,203
203   IF (NYEAR-NTIMMT(K,J) )204,205,205
202   WT=WEIGHT(K,J)
      GO TO 206
204   WT=WTON(K,J)
      GO TO 206
205   WT=WTMTL(K,J)*1.07407
206   TMCUST=TMCOST+WT*XNPMIX(K,J)*SALF(J)*XMCOST(J)
201   CONTINUE
      TLCOST=(1.05*XNPMIX(1,J)+1.02*XNPMIX(2,J)+0.99
     9*XNPMIX(3,J)+0.95*XNPMIX(4,J))*XLCOST(J)*SALE(J)
      DO 207 ITO=1,NOPT
207   TACOST=TACOST+ACOST(ITO)*TECHOP(ITO,J)*SALF(J)
      TVARCO(J)=TMCOST+TLCOST+TACOST
200   CONTINUE
      RETURN
```

```
      SUBROUTINE PRICE (*,NPRICE,NYEAR,NWRT,FSALE,FSIZE,XNPMIX,
     9SALE,CURPRC,ACTPRC,AVPRC,TSALE,ACTMIX,XMKTMX)
      DIMENSION XMKTMX(4),CURPRC(4),ACTMIX(4),ACTPRC(4),OLDCPM(4),
     9ACTCPM(4),SALE(4),FSIZE(4),XNPMIX(4,4),DUMMIX(4),DUMCPM(4)
      REAL K1,K2,K3,K4
      CONST=0.00001695117
91    READ(NPRICE,92,ERR=93)NOW,XMKTMX
92    FORMAT (I,4F)
      IF(NYEAR-NOW)93,94,91
94    DO 90 K=1,4
      ACTMIX(K)=FSALE*FSIZE(K)
      DO 95 J=1,4
95    ACTMIX(K)=ACTMIX(K)+XNPMIX(K,J)*SALE(J)
90    ACTMIX(K)=ACTMIX(K)/TSALE
      OLDCPM(1)=0.14046826+CURPRC(1)*CONST
      OLDCPM(2)=0.13367198+CURPRC(2)*CONST
      OLDCPM(3)=0.1243909+CURPRC(3)*CONST
      OLDCPM(4)=0.1076091+CURPRC(4)*CONST
      K1=OLDCPM(1)*(XMKTMX(2)+XMKTMX(3)+XMKTMX(4))/(OLDCPM(2)
     9*XMKTMX(2)+OLDCPM(3)*XMKTMX(3)+OLDCPM(4)*XMKTMX(4))
      K1=XMKTMX(1)*(K1**8.84702)/(1.0-XMKTMX(1))
      K2=OLDCPM(2)*(XMKTMX(1)+XMKTMX(3)+XMKTMX(4))/(OLDCPM(1)
     9*XMKTMX(1)+OLDCPM(3)*XMKTMX(3)+OLDCPM(4)*XMKTMX(4))
      K2=XMKTMX(2)*(K2**1.98095)/(1.0-XMKTMX(2))
      K3=(OLDCPM(3)*XMKTMX(3)+OLDCPM(4)*XMKTMX(4))/(XMKTMX(3)+
     9XMKTMX(4))
      K3=K3*(XMKTMX(1)+XMKTMX(2))/(OLDCPM(1)*XMKTMX(1)+OLDCPM(2)
     9*XMKTMX(2))
      K3=(XMKTMX(3)+XMKTMX(4))*(K3**2.75703)/(1.0-XMKTMX(3)-XMKTMX(4))
      K4=(OLDCPM(4)/OLDCPM(3))**11.9101
      K4=XMKTMX(4)*K4/XMKTMX(3)
      NUMBER=10
      C=0.7
      CINC=0.1
      NUM=7
      ERRMIN=100.0
900   DO 96 NUMB=1,NUM
      DO 97 K=1,4
97    DUMMIX(K)=ACTMIX(K)*C
      DUMCPM(4)=OLDCPM(4)
      ALPHA3=(DUMMIX(4)/(DUMMIX(3)*K4))**(-1.0/11.9101)
      DUMCPM(3)=DUMCPM(4)/ALPHA3
      ALPHA1=(DUMMIX(1)/((1.0-DUMMIX(1))*K1))**(-1.0/8.84702)
      ALPHA2=(DUMMIX(2)/((1.0-DUMMIX(2))*K2))**(-1.0/1.98095)
      THETA1=(ALPHA1*DUMMIX(2))/(DUMMIX(2)+DUMMIX(3)+DUMMIX(4))
      THETA2=ALPHA1*(DUMMIX(3)*DUMCPM(3)+DUMMIX(4)*DUMCPM(4))
      THETA2=THETA2/(DUMMIX(2)+DUMMIX(3)+DUMMIX(4))
      THETA3=(DUMMIX(1)+DUMMIX(3)+DUMMIX(4))/(ALPHA2*DUMMIX(1))
      THETA4=ALPHA2*(DUMMIX(3)*DUMCPM(3)+DUMMIX(4)*DUMCPM(4))
      THETA4=THETA4/(ALPHA2*DUMMIX(1))
      DUMCPM(2)=(THETA2+THETA4)/(THETA3-THETA1)
      DUMCPM(1)=THETA2+THETA1*DUMCPM(2)
      ERROR=(DUMCPM(3)*DUMMIX(3)+DUMCPM(4)*DUMMIX(4))*(DUMMIX(1)
     9+DUMMIX(2))
      ERROR=ERROR/((DUMCPM(1)*DUMMIX(1)+DUMCPM(2)*DUMMIX(2))*
     9(DUMMIX(3)+DUMMIX(4)))
      ERROR=ERROR-((DUMMIX(3)+DUMMIX(4))/((1.0-DUMMIX(3)-
     9DUMMIX(4))*K3))**(-1.0/2.75703)
      IF (ERROR)949,950,950
949   ERROR=-ERROR
```

```
950     IF (ERROR-ERRMIN)98,96,96
98      ERRMIN=ERROR
        CMIN=C
        DO 99 K=1,4
99      ACTCPM(K)=DUMCPM(K)
96      C=C+CINC
        IF (NUMBER) 901,901,902
902     C=CMIN-0.08
        CINC=0.005
        NUM=32
        NUMBER=-10
        GO TO 900
901     ACTPRC(1)=(ACTCPM(1)-0.14046826)/CONST
        ACTPRC(2)=(ACTCPM(2)-0.13367198)/CONST
        ACTPRC(3)=(ACTCPM(3)-0.1243909)/CONST
        ACTPRC(4)=(ACTCPM(4)-0.1076091)/CONST
        DUMMY=0.0
        DO 991 K=1,4
991     DUMMY=DUMMY+ACTMIX(K)*ACTPRC(K)
        DO 992 K=1,4
992     ACTPRC(K)=AVPRC*ACTPRC(K)/DUMMY
        RETURN
93      RETURN 1
```

```
SUBROUTINE FINANC (BVLNB,CAPFE,ANNLNB,BVMNE,ANNMNE,
9BVTOOL,ANNTOL,DEBT,DEPLNB,DEPMNE,AMOPER,RATINT
9,EQUITY,DIVDND,DEP,AMORT,ENTRST,DIV,J,NWRT)
DIMENSION BVLNB(4),BVMNE(4),BVTOOL(4),EQUITY(4),DEBT(4),
9ANNLNB(4),ANNMNE(4),ANNTOL(4),DEPLNB(4),AMOPER(4),
9DEPMNE(4),RATINT(4),TAXRAT(4),DIVDND(4),OTHCAP(4)
9,CAPFE(4)
BVLNB(J)=BVLNB(J)+   0.05                    *CAPFE(J)+ANNLNB(J)
BVMNE(J)=BVMNE(J)+  0.35                     *CAPFE(J)+ANNMNE(J)
BVTOOL(J)=BVTOOL(J)+     0.6                *CAPFE(J)+ANNTOL(J)
DEP=DEPLNB(J)*BVLNB(J)+DEPMNE(J)*BVMNE(J)
AMORT=AMOPER(J)*BVTOOL(J)
ENTRST=RATINT(J)*(DEBT(J)+CAPFE(J)+ANNLNB(J)+
9ANNMNE(J)+ANNTOL(J))
DIV=EQUITY(J)*DIVDND(J)
BVLNB(J)=BVLNB(J)*(1.0-DEPLNB(J))
BVMNE(J)=BVMNE(J)*(1.0-DEPMNE(J))
BVTOOL(J)=BVTOOL(J)*(1.0-AMOPER(J))
RETURN
```

```
      SUBROUTINE PROFRM (J,NWRT,XNPMIX,ACTPRC,SNA,DIV,SALE,RND,
     9XMRR,RET,OTHTAX,DEP,AMORT,ENTRST,TVARCO,TAXRAT,CAPFE,
     9ANNLNB,ANNMNE,ANNTOL,DEBT,NY   ,
     9EAR,EQUITY,OTHCAP,RETPRO,BVLNB,BVMNE,
     9BVTOOL,IPR,JPR,ISUM,ACTMIX,XMKTMX,NEND,IDET,
     9SIMDEB,SIMRET,SIMPRO,NT,HYPOAV,SIMHYP)
      DIMENSION XNPMIX(4,4),ACTPRC(4),SNA(4),RND(4),XMRR(4),RET(4),
     9OTHTAX(4),TVARCO(4),TAXRAT(4),CAPFE(4),ANNLNB(4)
     9,ANNMNE(4),ANNTOL(4),DEBT(4),EQUITY(4),OTHCAP(4),RETPRO(4),
     9BVLNB(4),BVMNE(4),BVTOOL(4),SALE(4),IPR(4),JPR(4
     9),ISUM(4),REVNUE(4),ATPRFT(4),CAPINV(4),
     9CSHFLO(4),XDEBT(4),XRETPR(4),BREAK(4),XSALE(4),XBREAK(4)
     9,ACTMIX(4),XMKTMX(4),SIMDEB(100,4),SIMRET(100,4),SIMPRO(100,4)
     9,HYPOAV(4),SIMHYP(100,4)
      REVNUE(J)=0
      Z=0.78
      DO 800 K=1,4
      REVNUE(J)=REVNUE(J)+XNPMIX(K,J)*ACTPRC(K)*Z*SALE(J)
800   Z=Z+0.03
      GO TO (5001,5002,5003,5004)J
5001  SNA(J)=3.352E8+1.75E-2*REVNUE(J)
      RND(J)=4.488E8+1.234E-2*REVNUE(J)
      XMRR(J)=2.826E8+4.529E-2*REVNUE(J)
      GO TO 5005
5002  SNA(J)=3.974E8+6.426E-3*REVNUE(J)
      RND(J)=-97.07E6+3.865E-2*REVNUE(J)
      XMRR(J)=1.509E8+1.754E-2*REVNUE(J)
      GO TO 5005
5003  SNA(J)=1.201E8+1.687E-2*REVNUE(J)
      RND(J)=5.45E7+1.323E-2*REVNUE(J)
      XMRR(J)=7.545E7+2.296E-2*REVNUE(J)
      GO TO 5005
5004  SNA(J)=6.287E7+3.481E-2*REVNUE(J)
      RND(J)=1.675E7+8.4E-3*REVNUE(J)
      XMRR(J)=6.34E6+1.679E-2*REVNUE(J)
5005  FIXCOS=SNA(J)+RND(J)+XMRR(J)+RET(J)+OTHTAX(J)+DEP+AMORT
      IF (ENTRST) 811,812,812
811   OPROFT=REVNUE(J)-TVARCO(J)-FIXCOS
      PRETAX=OPROFT-ENTRST
      TAX=TAXRAT(J)*PRETAX
      ATPRFT(J)=PRETAX-TAX
      GO TO 815
812   FIXCOS=FIXCOS+ENTRST
      OPROFT=REVNUE(J)-TVARCO(J)-FIXCOS
      TAX=TAXRAT(J)*OPROFT
      ATPRFT(J)=OPROFT-TAX
815   CAPINV(J)=CAPFE(J)+ANNLNB(J)+ANNMNE(J)+ANNTOL(J)
      CSHFLO(J)=ATPRFT(J)+DEP+AMORT-CAPINV(J)-DIV
      DEBT(J)=DEBT(J)-CSHFLO(J)
      RETPRO(J)=RETPRO(J)+ATPRFT(J)-DIV
      BREAK(J)=FIXCOS*SALE(J)/(REVNUE(J)-TVARCO(J))
      REVNUE(J)=REVNUE(J)/1.0E6
      ATPRFT(J)=ATPRFT(J)/1.0E6
      CAPINV(J)=CAPINV(J)/1.0E6
      CAPFE(J)=CAPFE(J)/1.0E6
      CSHFLO(J)=CSHFLO(J)/1.0E6
      XDEBT(J)=DEBT(J)/1.0E6
      XRETPRO(J)=RETPRO(J)/1.0E6
      IF (IDET-1)3300,1891,3300
1891  IF (JPR(J)) 890,890,891
```

```
891      IF(IPR(1)=99)893,894,893
893      DO 892 L=1,10
         IF (NYEAR=IPR(L))892,894,892
892      CONTINUE
         GO TO 890
894      GO TO (801,802,803,804)J
801      WRITE (NWRT,851)
851      FORMAT(1H1,30X,'GENERAL MOTORS')
         GO TO 805
802      WRITE (NWRT,852)
852      FORMAT (1H1,30X,'FORD')
         GO TO 805
803      WRITE (NWRT,853)
853      FORMAT(1H1,30X,'CHRYSLER')
         GO TO 805
804      WRITE (NWRT,854)
854      FORMAT (1H1,30X,'AMC')
805      WRITE (NWRT,850)NYEAR
850      FORMAT (20X,'INCOME STATEMENT FOR YEAR 19',I2)
         WRITE (NWRT,855) REVNUE(J)
855      FORMAT (T3,'SALES REVENUE',T45,F10.1)
         X=TVARCO(J)/1.0E6
         WRITE (NWRT,856)X
856      FORMAT (T3,'VARIABLE COSTS',T45,F10.1)
         X1=SNA(J)/1.0E6
         X2=END(J)/1.0E6
         X3=XMPR(J)/1.0E6
         X4=RET(J)/1.0E6
         DEP=DEP/1.0E6
         AMORT=AMORT/1.0E6
         X5=OTHTAX(J)/1.0E6
         FIXCOS=FIXCOS/1.0E6
         ENTRST=ENTRST/1.0E6
         OPROFT=OPROFT/1.0E6
         TAX=TAX/1.0E6
         DIV=DIV/1.0E6
         PRETAX=PRETAX/1.0E6
         WRITE (NWRT,857)X1,X2,X3,X4,X5,DEP,AMORT
857      FORMAT (T3,'FIXED COSTS'/T6,'SEL & ADM',T30,F10.1/T6,'RES &
        9DEV',T30,F10.1/T6,'MAIN. REP. & REA.',T30,F10.1/T6,'RET
        9IREMENT',T30,F10.1/T6,'NON-INCOME TAX',T30,F10.1/T6,'DEPRE
        9CIATION',T30,F10.1/T6,'AMORTISATION',T30,F10.1)
         IF (ENTRST)806,807,807
807      WRITE (NWRT,858)ENTRST
858      FORMAT(T6,'INTEREST',T30,F10.1)
806      WRITE(NWRT,859)FIXCOS
859      FORMAT(T45,F10.1)
         IF (ENTRST)808,809,809
809      WRITE (NWRT,860)OPROFT,TAX,ATPRFT(J)
860      FORMAT (T3,'PRE-TAX INCOME',T45,F10.1/T3,'INCOME TAX',
        9T45,F10.1/T3,'AFTER-TAX INCOME',T45,F10.1)
         GO TO 810
808      ENTRST=-ENTRST
         WRITE (NWRT,861)OPROFT,ENTRST,PRETAX,TAX,ATPRFT(J)
861      FORMAT(T3,'OPERATING PROFIT',T45,F10.1/T3,'INTEREST
        9 EARNED',T45,F10.1/T3,'PRE-TAX INCOME',T45,F10.1/T3,
        9'INCOME TAX',T45,F10.1/T3,'NET INCOME',T45,F10.1)
810      WRITE (NWRT,862)NYEAR
862      FORMAT (1H-,20X,'CASH FLOW STATEMENT FOR YEAR 19',
        9I2/T10,'SOURCES',T40,'USES')
```

```
      IF (ATPRFT(J))840,841,841
841   WRITE (NWRT,863)ATPRFT(J),CAPINV(J),DEP,DIV
863   FORMAT (T3,'NET INCOME',T20,F10.1,T35,'CAP INV',
     9T50,F10.1/T3,'DEPRECIATION',T20,F10.1,T35,
     9'DIVIDEND',T50,F10.1)
      IF (CSHFLO(J))821,820,820
820   WRITE (NWRT,864)AMORT,CSHFLO(J)
864   FORMAT (T3,'AMORTISATION',T20,F10.1,T35,'DEBT RED',
     9T50,F10.1)
      TOTAL=ATPRFT(J)+DEP+AMORT
      WRITE (NWRT,865)TOTAL,TOTAL
865   FORMAT(T8,'TOTAL',T20,F10.1,T40,'TOTAL',T50,F10.1)
      GO TO 822
821   TOTAL=ATPRFT(J)+DEP+AMORT-CSHFLO(J)
      X=-CSHFLO(J)
      WRITE (NWRT,866)AMORT,X,TOTAL,TOTAL
866   FORMAT(T3,'AMORTISATION',T20,F10.1/T3,'DEBT INC',T20,
     9F10.1/T8,'TOTAL',T20,F10.1,T40,'TOTAL',T50,F10.1)
      GO TO 822
840   IF (CSHFLO(J))842,843,843
843   TOTAL=DEP+AMORT
      X=-ATPRFT(J)
      WRITE (NWRT,2880) DEP,X,AMORT,CAPINV(J),DIV,CSHFLO(J)
     9,TOTAL,TOTAL
2880  FORMAT (T3,'DEPRECIATION',T20,F10.1,T35,'NET LOSS',
     9T50,F10.1/T3,'AMORTISATION',T20,F10.1,T35,'CAP INV',
     9T50,F10.1/T35,'DIVIDEND',T50,F10.1/T35,'DBT RED',
     9T50,F10.1/T8, 'TOTAL',T20,F10.1,T40,'TOTAL',T50,F10.1)
      GO TO 822
842   TOTAL=DEP+AMORT-CSHFLO(J)
      X1=-CSHFLO(J)
      X2=-ATPRFT(J)
      WRITE(NWRT,881)DEP,X2,AMORT,CAPINV(J),X1,DIV,TOTAL,TOTAL
881   FORMAT (T3,'DEPRECIATION',T20,F10.1,T35,'NET LOSS',
     9T50,F10.1/T3,'AMORTISATION',T20,F10.1,T35,'CAP INV',
     9T50,F10.1/T3,'DEBT INC',T20,F10.1,T35,'DIVIDEND',
     9T50,F10.1/T8,'TOTAL',T20,F10.1,T40,'TOTAL',T50,F10.1)
822   WRITE (NWRT,867)NYEAR
867   FORMAT (1H-,20X,'BALANCE SHEET FOR YEAR 19',I2)
      X1=BVLNB(J)/1.0E6
      X2=BVMNE(J)/1.0E6
      X3=BVTOOL(J)/1.0E6
      X5=OTHCAP(J)/1.0E6
      X4=EQUITY(J)/1.0E6
      WRITE(NWRT,868)X1,X4
868   FORMAT (T3,'LAND &BLDG',T20,F10.1,T35,'EQUITY',T50,F10.1)
      IF (XDEBT(J))824,823,823
823   WRITE (NWRT,869)X2,XDEBT(J)
869   FORMAT (T3,'M/C &EQPT',T20,F10.1,T35,'DEBT',T50,F10.1)
      GO TO 825
824   IF(XRETPR(J))826,827,827
827   WRITE (NWRT,870)X2,XRETPR(J)
870   FORMAT (T3,'M/C & EQPT',T20,F10.1,T35,'RETAINED INCOME'
     9,T50,F10.1)
      X6=-XDEBT(J)
      WRITE(NWRT,871)X3,X5,X6
871   FORMAT (T3,'TOOLING',T20,F10.1/T3,'OTHER ASSETS',T20,
     9F10.1/T3,'CREDITS',T20,F10.1)
      TOTAL=X4+XRETPR(J)
      WRITE(NWRT,872)TOTAL,TOTAL
```

```
872     FORMAT (T8,'TOTAL',T20,F10.1,T40,'TOTAL',T50,F10.1)
        GO TO 890
826     WRITE(NWRT,873)
873     FORMAT (' DEBT AND RET INCOME NEGATIVE')
        GO TO 890
825     IF (XRETPR(J))828,829,829
829     WRITE (NWRT,874) X3,XRETPR(J),X5
874     FORMAT (T3,'TOOLING',T20,F10.1,T35,'RETAINED INCOME',T50
       9,F10.1/T3,'OTHER ASSETS',T20,F10.1)
        TOTAL=X4+XDEBT(J)+XRETPR(J)
        WRITE(NWRT,875)TOTAL,TOTAL
875     FORMAT(T8,'TOTAL',T20,F10.1,T40,'TOTAL',T50,F10.1)
        GO TO 890
828     X6=-XRETPR(J)
        TOTAL=XDEBT(J)+X4
        WRITE (NWRT,876)X3,X5,X6,TOTAL,TOTAL
876     FORMAT (T3,'TOOLING',T20,F10.1/T3,'OTHER ASSETS',T20,
       9F10.1/T3,'RETAINED LOSSES',T20,F10.1/T8,'TOTAL',T20,
       9F10.1,T40,'TOTAL',T50,F10.1)
890     IF (J-4)830,831,830
831     IF(ISUM(1)-99)832,833,832
832     DO 834 L=1,10
        IF (NYEAR-ISUM(L))834,833,834
834     CONTINUE
        GO TO 830
833     WRITE (NWRT,877)NYEAR
877     FORMAT (1H1,20X,'SUMMARY STATEMENT FOR YEAR 19',I2/T20,
       9'LARGE',T30,'MID-SIZE',T40,'COMPACT',T50,'SUBCOMPACT')
        WRITE (NWRT,878)ACTMIX,XMKTMX,ACTPRC
878     FORMAT (' MIX PRODUCED',T20,F7.3,T30,F7.3,T40,F7.3,T50,F7.3
       9/' MIX DESIRED',T20,F7.3,T30,F7.3,T40,F7.3,T50,F7.3/
       9' AVG PRICE',T20,F7.0,T30,F7.0,T40,F7.0,T50,F7.0///)
        WRITE (NWRT,879)
879     FORMAT (T20,'GEN MOT',T30,'FORD',T40,'CHRY',T50,'AMC'//)
        DO 885 K=1,4
        XSALE(K)=SALE(K)/1.0E6
885     XBREAK(K)=BREAK(K)/1.0E6
        WRITE(NWRT,880)XSALE,XBREAK,REVNUE,ATPRFT,CAPINV,CAPEE,
       9CSHFLO,XDEBT,XRETPR,NYPDAV
880     FORMAT (' SALE (MILLIONS)',T20,F7.3,T30,F7.3,T40,F7.3,
       9T50,F7.3/' BREAKEVEN (MIL.)',T20,F7.3,T30,F7.3,T40,F7.3
       9,T50,F7.3//' REVENUE',T20,F8.0,T30,F8.0,T40,F8.0,T50,
       9F8.0/' NET INCOME',T20,F8.0,T30,F8.0,T40,F8.0,T50,F8.0/
       9' CAP INV (TOT)',T20,F8.0,T30,F8.0,T40,F8.0,T50,F8.0/
       9' CAP INV (ANES)',T20,F8.0,T30,F8.0,T40,F8.0,T50,F8.0/
       9' NET CASH FLOW',T20,F8.0,T30,F8.0,T40,F8.0,T50,F8.0/
       9' DEBT',T20,F8.0,T30,F8.0,T40,F8.0,T50,F8.0/
       9' RET INCOME',T20,F8.0,T30,F8.0,T40,F8.0,T50,F8.0//
       9' FUEL ECONOMY WITHOUT'/' MIX SHIFTS',T20,F8.2,
       9T30,F8.2,T40,F8.2,T50,F8.2)
3300    IF (NYEAR-KEND)830,1301,830
1301    DO 1302 J=1,4
        SIMNYP(NT,J)=NYPDAV(J)
        SIMDEB(NT,J)=XDEBT(J)
        SIMRET(NT,J)=XRETPR(J)
1302    SIMPRO(NT,J)=ATPRFT(J)
830     RETURN
```

```
      SUBROUTINE SIMULA (NTIME,ARRAY,FRA10,FRA25,FRA50,
     9FRA75,FRA90)
      DIMENSION ARRAY(100)
      NDUM=NTIME-1
      DO 6000 IJK=1,NTIME
      DO 6000 JK=1,NDUM
      IF (ARRAY(JK)-ARRAY(JK+1)) 6000,6000,6001
6001  DUM=ARRAY(JK)
      ARRAY(JK)=ARRAY(JK+1)
      ARRAY(JK+1)=DUM
6000  CONTINUE
      N10=NTIME*0.1
      N25=NTIME*.25
      N50=NTIME*.5
      N75=NTIME*.75
      N90=NTIME*.9
      FRA10=ARRAY(N10)
      FRA25=ARRAY(N25)
      FRA50=ARRAY(N50)
      FRA75=ARRAY(N75)
      FRA90=ARRAY(N90)
      RETURN
```

APPENDIX E

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APPENDIX F

Report of New Technology

This study develops a risk analysis model of the automobile industry in order to assess the impact of the Automotive Fuel Economy Standards (AFES) on each manufacturer in the industry. The study makes a methodological contribution by illustrating how to analyze a rather complex situation characterized by uncertainty by applying risk analysis. In the context under study, various pieces of data, mostly drawn from several different reports written or sponsored by DOT, are used to analyze the impact of the AFES on the automobile industry. The results yield some insight into what the probable impact of the AFES will be.

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